

# TRANSACTIONS

*of the*  
*American Society for Steel Treating*

Vol. VIII

September, 1925

No. 3

## THE SEVENTH ANNUAL CONVENTION SEPTEMBER 14 to 18

THE membership each year looks forward to the month of September because it means to them the gathering of the membership in annual convention.

The record maintained by the society in the proportion of its



The Cleveland Public Auditorium where the Seventh Annual Convention and National Steel Exposition will be held September 14 to 18, 1925.

membership in attendance at the annual convention has been noteworthy and unparalleled in the annals of technical societies. Last

year almost 60 per cent of the entire membership registered in attendance.

There must be reasons for this great enthusiasm and popularity, and these are not hard to find. Besides the value of getting together and meeting men in their own line of endeavor, there is the great inspirational and educational series of technical sessions which offer to the membership new developments in the lines of research and investigation, giving them new ideas that they may take home and make applicable to their own activity.

The 1925 convention in Cleveland, the technical program which is published elsewhere in this issue, needs but a careful perusal to demonstrate beyond all doubt that the technical portion of the program will maintain the high standard established at previous conventions.

The exposition has been the nucleus around which has centered a great amount of interest. There 200 manufacturers will have their products on display and in actual operation, offering to the membership an unparalleled opportunity to compare and observe the latest in the line of equipment. Some 43,000 attended the exposition in Boston last year and the attendance in Cleveland this year will undoubtedly be as large.

It behooves all of the members to exert a decided effort to be present. It is an opportunity that comes but once a year, and you owe it to yourself and your work not to permit this opportunity to pass unused.

**F**OR the convenience of those who have not as yet made their hotel reservations we are including the list of the principal Cleveland hotels and their rates. The map on the opposite page shows the location of these hotels in respect to the Public Auditorium and Public Square.

#### List of Cleveland Hotels

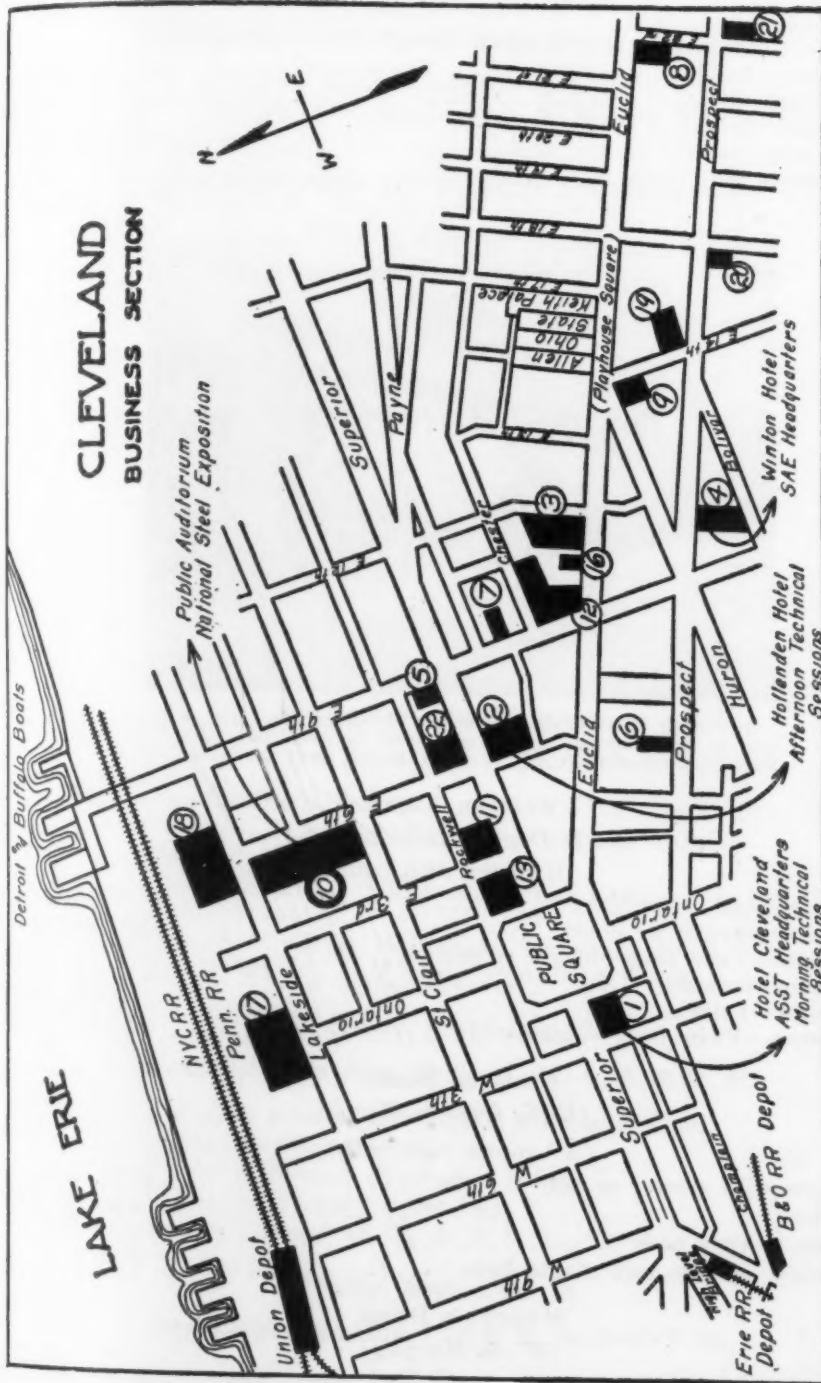
##### HOTEL CLEVELAND

(F. L. Bonneville, Asst. Mgr.)

##### CONVENTION HEADQUARTERS

(All rooms with bath)

|                           |   |
|---------------------------|---|
| Single rooms.....         | \$3.00, \$3.50, \$4.00, \$4.50, \$5.00, \$6.00, \$ 7.00 and \$ 8.00 |
| Double rooms.....         | 5.00, 5.50, 6.00, 6.50, 7.00, 8.00, 9.00 and 10.00                  |
| Double rooms—Twin beds .. | 7.00, 8.00, 9.00, 10.00, 12.00.                                     |
| Suites—one person.....    | \$12.00 and up  |
| Suites—two persons ....   | 14.00 and up  |
| Suites—three persons...   | \$20.00 and up  |
| Suites—four persons ...   | 22.00 and up  |



1. Hotel Cleveland
2. Hollenden Hotel
3. Statler Hotel
4. Winton Hotel
5. Olmsted Hotel
6. Colonial Hotel
7. Murphy's Hotel
8. New Amsterdam Hotel
9. Euclid Hotel
10. Public Auditorium
11. New Public Library
12. Union Trust Building
13. Post-Office
16. Stillman Theater
17. County Court House
18. City Hall
19. Hanna Theater
20. Y. W. C. A.
21. Y. M. C. A.

Map of Business Section of Cleveland Showing Location of Hotels, Theatres, etc.

HOLLENDEN HOTEL  
(Theo. DeWitt, Mgr.)  
(All rooms with bath)

|                              |                   |
|------------------------------|-------------------|
| Single rooms—inside .....    | \$3.00 to \$ 3.50 |
| Double rooms—inside .....    | 5.00 to 6.00      |
| Single rooms—outside .....   | 4.00 to 6.00      |
| Double rooms—outside .....   | 6.00 to 8.00      |
| Double rooms—twin beds ..... | 7.00 to 10.00     |
| Suites .....                 | 10.00 and up      |



The High Level Bridge spans the Cuyahoga River and Valley and is the Principal Artery of Travel between the East and West Sections of the City.

STATLER HOTEL  
(H. F. Dugan, Asst. to Mgr.)  
(All rooms with bath)

|  |                   |
|--|-------------------|
| Single rooms—inside or court .....           | \$3.00 to \$ 4.00 |
| Double rooms—inside or court .....           | 4.50 to 6.00      |
| Double rooms—Twin beds—inside or court ..... | 5.50 to 7.00      |
| Single rooms—outside .....                   | 4.00 to 7.00      |
| Double rooms—outside .....                   | 5.50 to 9.00      |
| Double rooms—Twin beds—outside .....         | 7.50 to 12.00     |

OLMSTED HOTEL  
(H. G. Ganson, Mgr.)  
(All rooms with bath)

|   |                  |
|---|------------------|
| Single rooms with shower or tub .....     | \$2.50 to \$3.00 |
| Double rooms .....                        | 4.00 to 6.00     |
| Double rooms—twin beds .....              | 6.00             |
| Double rooms—double and single beds ..... | 7.50             |

MURPHY'S HOTEL  
(W. L. Murphy)

|  |                |
|--|----------------|
| Single rooms without bath .....          | \$2.00         |
| Single rooms with bath .....             | 2.50 to \$3.00 |
| Double rooms without bath .....          | 3.50           |
| Double rooms with bath .....             | 5.00           |
| Rooms with 2 double beds with bath ..... | 8.00           |

OUTLINE OF EVENTS

SEVENTH ANNUAL CONVENTION A. S. S. T.

All morning technical sessions will be held in the Ball Room of the Cleveland Hotel. The afternoon sessions will be held in the Ball Room of the Hollenden Hotel.

REGISTRATION AT PUBLIC AUDITORIUM

Monday, September 14

Exposition open from 1:00 P. M. to 10:00 P. M.

- 10:00 A. M.—Technical Session, Ball Room, Cleveland Hotel.
- 1:00 P. M.—Exposition Opens. Registration Begins.
- 2:00 P. M.—Technical Session, Ball Room, Hollenden Hotel.

Tuesday, September 15

Exposition open from 1:00 P. M. to 10:00 P. M.

- 9:30 A. M.—Technical Session, Ball Room, Cleveland Hotel.
- 1:00 P. M.—Exposition Opens.
- 1:30 P. M.—Plant Visitation, Midland Steel Products Company or National Carbon Company.
- 2:00 P. M.—Technical Session, Ball Room, Hollenden Hotel.
- 9:30 P. M.—Annual Smoker and Entertainment.

Wednesday, September 16

Exposition open from 1:00 P. M. to 10:00 P. M.

- 9:30 A. M.—Annual Meeting of the A. S. S. T., Ball Room, Cleveland Hotel.
- 10:30 A. M.—Technical Session, Ball Room, Cleveland Hotel.
- 1:00 P. M.—Exposition Opens.
- 1:30 P. M.—Plant Visitation, White Motor Car Company or Van Dorn and Dutton Company.
- 2:00 P. M.—Technical Session, Ball Room, Hollenden Hotel.
- 9:30 P. M.—Annual Dance, Ball Room, Cleveland Hotel.

Thursday, September 17

Exposition open from 10:00 A. M. to 5:30 P. M.

- 9:30 A. M.—Technical Session, Ball Room, Cleveland Hotel.
- 10:00 A. M.—Exposition Opens.
- 2:00 P. M.—Technical Session, Hollenden Hotel.
- 5:30 P. M.—Exposition Closes for the Day.
- 6:30 P. M.—Annual Banquet of the A. S. S. T., Hotel Cleveland.

Friday, September 18

Exposition open from 1:00 P. M. to 10:00 P. M.

- 9:30 A. M.—Technical Session, Ball Room, Cleveland Hotel.
- 1:00 P. M.—Exposition Opens.
- 1:30 P. M.—Plant Visitation, F. H. Glidden Varnish Company or the American Steel and Wire Company, Cuyahoga Plant.
- 2:00 P. M.—Technical Session, Ball Room, Hollenden Hotel.
- 10:00 P. M.—Exposition Closes.

**TENTATIVE SCHEDULE OF PAPERS PROGRAM, SEVENTH  
ANNUAL CONVENTION, AMERICAN SOCIETY FOR STEEL  
TREATING, CLEVELAND, SEPTEMBER 14-18, 1925**

**MONDAY, SEPTEMBER 14**

**Morning Session**

Meeting in Ball Room, Hotel Cleveland.

- 10:00 A. M.—Welcome by Cleveland Chapter—H. A. Schwartz, Chairman  
Address of Welcome—Colonel J. B. Dillard, General Chairman  
Response—President W. S. Bidle

**Technical Session**

Chairman—H. A. Schwartz

- 10:15 A. M.—*Interpretation of Notched Bar Impact Test Results*—Paul Heymans, Massachusetts Institute of Technology, Cambridge, Mass.  
10:50 A. M.—*Chemical Composition of Tool Steels*—J. P. Gill and M. A. Frost, Vanadium Alloys Steel Co., Latrobe, Pa.  
11:25 A. M.—*Experiments with Nickel, Tantalum, Cobalt and Molybdenum in High Speed Steels*—H. J. French and T. G. Digges, Bureau of Standards, Washington, D. C.

**Afternoon Session**

- 1:00 P. M.—Exposition opens.  
2:00 P. M.—Technical Session—Ball Room, Hotel Hollenden.  
Chairman—Dr. A. E. White.  
2:00 P. M.—*Effect of Cold Work on Endurance and Other Properties of Metals*—D. J. McAdam, Jr., U. S. Naval Engineering Experiment Station, Annapolis, Md.  
2:40 P. M.—*Graphitization at Constant Temperature*—H. A. Schwartz, National Malleable & Steel Castings Co., Cleveland.  
3:20 P. M.—*Some Factors Affecting Coercive Force and Residual Induction of Some Magnet Steels*—J. R. Adams and F. E. Goeckler, Midvale Co., Nicetown, Philadelphia.

**Evening Session**

Exposition open until 10:00 P. M.

**TUESDAY, SEPTEMBER 15**

**Morning Session**

Meeting in Ball Room, Hotel Cleveland.

Chairman—Dr. J. A. Mathews.

- 9:30 A. M.—STEEL MELTING SESSION  
9:30 A. M.—*Proportion of Heat Treated Steel to Total Production*—C. J. Stark, Iron Trade Review, Cleveland.  
9:50 A. M.—*Acid Open Hearth Steel*—Radclyffe Furness, Midvale Co., Nicetown, Philadelphia.  
10:30 A. M.—*Basic Open Hearth Steel*—Edward Whitworth, Bourne-Fuller Co., Cleveland.  
11:15 A. M.—*Electric Furnace Steel*—F. T. Sisco, McCook Field, Dayton, Ohio.  
12:30 P. M.—METALLURGICAL EDUCATION SYMPOSIUM LUNCHEON  
Hotel Cleveland. Chairman—Dr. A. E. White.

**Afternoon Session**

- 1:00 P. M.—Exposition opens.  
1:30 P. M.—Plant Inspection, Midland Steel Products Company or National Carbon Company.  
2:00 P. M.—Technical Session—Ball Room, Hotel Hollenden.  
Chairman—Dr. Zay Jeffries.

- 2:00 P. M.—*Comparative Slow-Bend and Impact Notched Bar Tests on Some Metals*—S. N. Petrenko, Bureau of Standards, Washington, D. C.
- 2:40 P. M.—*Effect of Reheating on Cold Drawn Bars*—S. C. Spalding, Halcomb Steel Co., Syracuse, N. Y.
- 3:20 P. M.—*Application of the Mathematics of Probability to Experimental Data as a Basis for Appropriate Choice of Ferrous Materials*—B. D. Saklatwalla and H. T. Chandler, Vanadium Corporation of America, Bridgeville, Pa.

#### Evening Session

- 6:00 P. M.—DINNER MEETING OF COMMITTEE E-4, A. S. T. M.—Old Colony Club, Hollenden Hotel.
- 9:30 P. M.—ANNUAL SMOKER AND ENTERTAINMENT.  
Exposition open until 10:00 P. M.

### WEDNESDAY, SEPTEMBER 16

#### Morning Session

Meeting in Ball Room, Hotel Cleveland.

- 9:30 A. M.—ANNUAL MEETING OF THE AMERICAN SOCIETY FOR STEEL TREATING.  
Chairman—W. S. Bidle.  
Report of Chapter Delegates.  
Report of Officers.

#### Technical Session

Chairman—Dr. G. K. Burgess.

- 10:30 A. M.—*Retained Austenite—A Contribution to the Metallurgy of Magnetism*—Dr. J. A. Mathews, Crucible Steel Company of America, New York City.
- 11:15 A. M.—*On Martensite*—Dr. H. Hanemann, Technischen Hochschule, Charlottenburg, Germany. (To be presented by Dr. S. L. Hoyt.)

#### Afternoon Session

- 1:00 P. M.—Exposition opens.
- 1:30 P. M.—Plant Inspection, White Motor Car Company or Van Dorn and Dutton Company.
- 2:00 P. M.—Technical Session—Ball Room, Hollenden Hotel.  
Chairman—E. C. Bain.
- 2:00 P. M.—*The Carbon Content of Pearlite in Iron Carbon Alloys Containing One Per Cent Silicon*—Anson Hayes and H. U. Wakefield, Iowa State College, Ames, Iowa.
- 2:30 P. M.—*Irregular Carburization—Its Causes and Preventions*—W. J. Merten, Westinghouse Electric & Manufacturing Co., East Pittsburgh.
- 3:00 P. M.—*A Study of Dendritic Structure and Crystal Formation*—Bradley Stoughton and F. J. G. Duck, Lehigh University, Bethlehem, Pa.
- 3:30 P. M.—*Oil Burning Equipment for Industrial Furnaces*—M. H. Mahinney, General Furnace Co., Pittsburgh.

#### Evening Session

- 9:30 P. M.—ANNUAL GRAND BALL, Ball Room, Hotel Cleveland.  
Exposition open until 10:00 p. m.

### THURSDAY, SEPTEMBER 17

#### Morning Session

- Meeting in Ball Room, Hotel Cleveland.
- 9:30 A. M.—Technical Session.  
Chairman—Dr. Albert Sauveur.

- 9:30 A. M.—*Initial Temperature and Mass Effects in Quenching*—H. J. French and O. Z. Klopsch, Bureau of Standards, Washington, D. C.
- 10:20 A. M.—*On the Nature of Some Low-Tungsten Tool Steels*—M. A. Grossmann, United Alloy Steel Corp., Canton, Ohio, and E. C. Bain, Union Carbide & Carbon Research Laboratories, Long Island City, N. Y.
- 11:10 A. M.—*Effect of Cold Working on Hollow Cylinders*—Dr. F. C. Langenberg, Watertown Arsenal, Watertown, Mass.

#### Afternoon Session

- 2:00 P. M.—A Session Contributed by the American Society of Mechanical Engineers, Machine Shop Practice Division. Ball Room, Hollenden Hotel.  
*Modern Surface Grinding*—H. K. Spencer, Blanchard Machine Co., Cambridge, Mass.  
*Dies*—Mr. Keller, Keller Mechanical Engineering Corp., Brooklyn, N. Y.  
Titles of other papers to be supplied later.
- 2:00 P. M.—SYMPOSIUM OF HARDNESS TESTING COMMITTEE OF THE A. S. S. T., Hollenden Hotel.  
Chairman—A. E. Bellis.
- 2:00 P. M.—*Electric Ring for Verification of Brinell Hardness Testing Machines*—S. N. Petrenko, Bureau of Standards, Washington, D. C.
- 2:20 P. M.—*Some Comparisons between Rockwell and Brinell Hardness*—R. C. Brumfield, Cooper Union, New York City.
- 2:40 P. M.—*Hardness and Toughness of High Speed Steel as Affected by the Heat Treatment*—R. K. Barry, Barry Co., Muscatine, Iowa.
- 3:00 P. M.—*Stress-Strain Curve and the Characteristics Which Are Associated with Hardness*—H. P. Hollnagel, General Electric Co., West Lynn, Mass.
- 3:20 P. M.—*English Hardness Testing Machine of the Brinell Principle*—O. W. Boston, University of Michigan, Ann Arbor, Mich.
- 3:40 P. M.—*The Durometer—An Instrument for Testing Hardness*—Dr. Albert Sauveur, Harvard University, Cambridge, Mass.
- 5:30 P. M.—Exposition closes for the day.

#### Evening Session

- 6:30 P. M.—ANNUAL BANQUET OF THE A. S. S. T., Ball Room, Hotel Cleveland.

### FRIDAY, SEPTEMBER 18

#### Morning Session

- 9:30 A. M.—Technical Session—Ball Room, Hotel Cleveland.  
Chairman—Bradley Stoughton.
- 9:30 A. M.—*Carburization by Solid Cements*—W. E. Day, Jr., International Motor Co., New Brunswick, N. J.
- 10:20 A. M.—*Dilatometric Method of Heat Treatment*—O. E. Harder, R. L. Dowdell and A. C. Forsythe, University of Minnesota, Minneapolis, Minn.
- 11:10 A. M.—*What Happens When Metal Fails by Fatigue*—Professor H. E. Moore, University of Illinois, Urbana, Ill.

#### Afternoon Session

Exposition opens at 1 P. M.

1925.

- 1:30 P. M.—Plant Inspection, F. H. Glidden Company or the American Steel and Wire Company, Cuyahoga Plant.
- 2:00 P. M.—Technical Session, Ball Room, Hollenden Hotel.  
Chairman—H. M. Boylston.
- 2:00 P. M.—*Why Metal Warps and Cracks*—J. F. Keller, Purdue University, Lafayette, Ind.
- 2:40 P. M.—*Design and Operation of Furnaces for Salt Baths*—Sam Tour, Doehler Die Castings Co., Batavia, N. Y.
- 3:20 P. M.—*Welding Steel Tubing and Sheet with Chromium-Molybdenum Welding Wire*—F. T. Sisco and H. W. Boulton, McCook Field, Dayton, Ohio.

## Evening Session

- 10:00 P. M.—Exposition officially closes.

**LIST OF EXHIBITORS AND WHAT THEY WILL EXHIBIT AT THE  
NATIONAL STEEL AND MACHINE TOOL EXPOSITION,  
CLEVELAND, SEPTEMBER 14-18, 1925**

All spaces Nos. 1 to 150 located on Arena Floor and Stage

All spaces Nos. 200 to 300 located in Exposition Hall

**Abrasive Machine Tool Co., E. Providence, R. I. Booth 246.**

Exhibiting (in operation): No. 3 horizontal spindle surface grinder;  
No. 33 vertical spindle surface grinder.

In attendance: K. B. MacLeod and N. D. MacLeod.

**Acme Machine Tool Company, Cincinnati. Booth 250.**

Exhibiting (in operation): No. 2 full universal turret lathe.

In attendance: C. Meier and Mr. Stehn.

**Air Reduction Sales Co., New York City. Booths 271 and 281.**

Exhibiting (in operation): Airco Oxygen, Airco acetylene and Airco calorene in cylinders. Airco-Davis-Bournonville welding and cutting torches, regulators and supplies. Airco-Davis-Bournonville oxygen discharge manifold. Radiograph for oxyacetylene machine cutting. Oxygraph for oxyacetylene machine cutting.

In attendance: G. F. Weiser, industrial engineering department; W. F. Cooper, J. H. Gjerdum, C. E. Hobbs.

**Ajax Manufacturing Co., Cleveland. Booth 3.**

Exhibiting: Model Ajax upsetting forging machine. Model Ajax board drop hammer and sample upset forgings.

In attendance: J. R. Blakeslee, president; H. D. Heman, general manager; A. L. Guilford, western manager; Gordon Fristoe, sales engineer, and W. W. Criley, J. A. Murry, Eastern manager.

**Allen Co., Charles G., Barre, Mass. Booth 213.**

Exhibiting (in operation): One four spindle Allen ball bearing power feed drilling machine. One four spindle Allen ball bearing drilling machine, showing different types of heads.

In attendance: Harding Allen and C. G. Allen.

**American Gas Furnace Co., Elizabeth, N. J. Booths 220, 221 and 222.**

Exhibiting (in operation): Gas carburizing machine, salt bath furnaces for preheating high speed and for drawing carbon and high speed steel. High speed steel oven furnace operating on high pressure gas

supplied by our Rotary gas booster. Burners and blowpipes, automatic temperature controller and high pressure blower,—new type.

In attendance: P. C. Osterman, vice-president; W. H. Kelsey, Cleveland representative; John Mehrman, chief demonstrator; Theodore Farwick, Sr., automatic temperature controller and burner representative; Gustav Schwab, M. E.

**American Resistor Company, Philadelphia. Booth 116A.**

Exhibiting (in operation): GLOBAL non-metallic electric heating elements in actual operation at temperatures ranging from 1600 to 3000 degrees Fahr. High speed steel heat treating and forging furnaces equipped with GLOBAL non-metallic heating elements, operating at temperatures up to 2400 degrees Fahr. Laboratory and assay furnaces equipped with GLOBAL non-metallic heating elements operating at temperatures up to 3000 degrees Fahr.

In attendance: J. A. Steinmetz, president; W. W. Perkins, vice president and treasurer; W. E. Duersten, vice president in charge of operations; B. G. Tarkington, Oscar Brophy, H. N. Shaw and K. E. Rogers, sales engineers.

**American Stainless Steel Co., Pittsburgh. Booth 81.**

Exhibiting: Varied assortment of articles made from stainless steel and stainless iron.

In attendance: J. C. Neale, president; C. S. Bunting, secretary.

**American Tool Works, Cincinnati. Booths 224 and 225.**

Exhibiting (in operation): 14"x6' motor driven lathe; 24" motor driven shaper; 24"x12' heavy pattern motor driven lathe; 5' triple purpose radial drill, motor driven; 3' maxi-speed sensitive radial drill, motor driven; 3' gear box belt driven radial drill.

In attendance: J. C. Hussey, Western sales manager.  
Flix Kremp, metallurgist.

**Ames & Co., B. C., Waltham, Mass. Booth 210.**

Exhibiting (in operation): One bench lathe mounted on cabinet; one bench milling machine; and one triplex lathe.

In attendance: Warren Ames, president.

**Anchor Drawn Steel Co., Latrobe, Pa. Booth 84.**

Exhibiting: "Gold Anchor" high speed drill rods; "Blue Anchor" carbon drill rods; "Red Anchor" carbon drill rods; cold drawn threading chaser steel in high speed, carbon and alloy grades; cold drawn tap steel in high speed, 1½ per cent tungsten and alloy grades; cold drawn stainless steel and iron in rounds (down to .103"), and special shapes; cold drawn special shapes in high speed, tool steels, alloy steels, carbon steels and screw stock; cold drawn key stock and cold drawn specialties.

In attendance: D. R. Wilson, president; G. W. Morrison, vice president in charge of operations; W. W. Noble, vice president in charge of sales.

**Andresen and Associates, F. C. Inc., Pittsburgh. Booth 11.**

Exhibiting: "Fuels and Furnaces."

In attendance: E. C. Cook, managing editor, and I. S. Wishoski, engineering editor.

**Armstrong-Blum Mfg. Co., Chicago. Booth 45.**

Exhibiting (in operation): Marvel automatic high speed saw; Marvel metal band saw; Marvel hack sawing machines; Marvel punch, shear and bender.

In attendance: H. J. Blum, secretary.

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**Armstrong Cork and Insulating Co., Pittsburgh. Booth 57.**

Exhibiting: Cork and cork specialties, Armstrong's corkboard; Nonpareil cork covering; Nonpareil high pressure covering (insulating); Nonpareil and Armstrong's insulating brick; Linotile and Armstrong's cork tile.

In attendance: J. T. Gower, Cleveland manager; P. W. Adams, N. P. Waite, J. A. Wilson.

**Atkins & Co., E. C., Indianapolis. Booth 100.**

Exhibiting (in operation): Atkins silver steel hack saw blades; Atkins No. 3 metal band saw machine; Atkins No. 18 and No. 7 Kwik-Kut machines.

In attendance: E. S. Norvell, manager metal cutting department; H. L. Pruner, district metal saw specialist; A. Mertz, Cleveland representative; W. R. Chapin, metallurgist; William Appel, chemist.

**Atlas Alloy Steel Corp., Dunkirk, N. Y. Booth 118.**

Exhibiting: High speed carbon and alloy tool steels in various forms, such as hot rolled, cold drawn, forged, etc.

In attendance: A. F. Dohn, president; F. B. Lounsberry, vice president and metallurgist; C. P. Burgess, assistant to president; Walter Bould, assistant treasurer; W. H. Wills, assistant metallurgist; D. G. Hoyt, assistant metallurgist; W. H. White, Cleveland district manager; J. S. Marlowe and J. E. Jones, salesmen.

**Avey Drilling Machine Co., Cincinnati. Booth 253.**

Exhibiting (in operation): Two spindle No. 2 sensitive drills, one with automatic feed and one with tapping unit; one single spindle No. 2 Aveymatic with motor on spindle; one single spindle No. 1½ high speed hand feed of new design of motor mounting; one two spindle No. 3, one spindle with Aveymatic feed, one with tapping head.

In attendance: J. G. Hey, J. Mirrieles, Mr. Hazeldine, and L. B. Patterson, president.

**Badger Tool Co., Beloit, Wis. Booth 258.**

Exhibiting (in operation): No. 220 double wheel surface grinder; No. 8 belt driven disc grinder with power operated lever feed table.

In attendance: E. B. Gardner, John Nielson.

**Baker Brothers, Toledo, O. Booth 246.**

Exhibiting (in operation): No. 24 cam feed drill; No. 3 two way horizontal boring and drilling-machine; No. 525 heavy duty drill.

In attendance: H. Tigges, and William Baker, treasurer; W. W. Elliott, G. E. Hallenbeck, vice president.

**Bath & Co., Inc., John, Worcester, Mass. Booth 47.**

Exhibiting: Ground thread tools including ground taps, hobs, roll thread dies, plug thread gages and chasers. Bath internal micrometers.

Whereas we featured last year simply our precision thread grinding work, this year we will supplement our standard exhibit with samples of worn out taps showing the remarkable production records secured from Bath products. We will feature this year our new ground thread hand book which will be unique. It will embrace not only a catalog of Bath ground thread tools, but also a short history of ground thread work, together with a section of general information and "tapping helps."

In attendance: John Bath, president and treasurer; J. C. Bath, vice president.

**Bausch & Lomb Optical Co., Rochester, N. Y. Booth 24.**

Exhibiting: Metallographic equipment, with some new features. Contour measuring projector and several new optical devices for shop use.

In attendance: W. L. Patterson, I. L. Nixon, H. L. Shippy, F. C. Lau, L. V. Foster.

**Bellevue Industrial Furnace Co., Detroit. Booth 121.**

Exhibiting: Bellevue high speed furnace with section cut away showing inner construction; Bellevue high temperature fire brick; Bellevue oil and gas burners.

In attendance: W. E. Hinz, president and general manager; L. J. Raymo, sales manager.

**Bellis Heat Treating Company, Branford, Conn. Booth 117.**

Exhibiting: LAVITE, the ideal heating medium; LAVITE pots and furnaces with work that has been heat treated in LAVITE, including annealed wire, nickel silver, spoon blanks, watch cases, carbon steel gears, punches and dies, hardened high speed steel form cutters, drills, etc. Annealed gold, brass and nickel strip and wire.

In attendance: A. E. Bellis, president; W. E. Hitchcock, treasurer; G. C. Davis, New England representative.

**Bethlehem Steel Company, Bethlehem, Pa. Booths 31-32, 20-21.**

Exhibiting: Educational exhibit, concentrating on Lehigh Mill products such as alloy and tool steels and miscellaneous merchant mill products and special sections. Interesting castings made from mixtures of Mayri iron, drop forgings and small difficult press forgings as well as some miscellaneous specialties.

In attendance: H. G. Walton, D. A. Barkley, R. MacDonald, C. E. Chamberlain, F. W. Baldwin, T. J. Fitzgibbons, R. S. Tucker, W. C. Cutler, J. C. Chandler, P. Kreulin, A. D. Smith, all of sales department. A. P. Spooner, engineer of tests; Robert Shimer, sales metallurgist; Walter Trumbauer, H. Wysor, director of research; A. D. Shankland, metallurgical inspector; G. A. Richardson, manager technical publicity department, and others.

**Bilton Machine Tool Co., Bridgeport, Conn. Booth 217.**

Exhibiting (in operation): No. 3½ and No. 6½ Pro-Ducto-Matic milling machines.

In attendance: E. A. Harper, vice president.

**Black & Decker Mfg. Co., Towson, Md. Booth 46.**

Exhibiting: Complete line of portable electric drills, bench and post drill stands, portable electric grinders, electric bench grinders, electric twist drill grinders, portable electric tappers and portable electric screw drivers and socket wrenches. All tools in actual operation, visualizing their adaptability to the various jobs most commonly met with in industrial work.

In attendance: S. D. Black, president; R. W. Proctor, sales manager; W. C. Allen, sales supervisor; R. D. Black, advertising manager; G. M. Buchanan, industrial sales department; R. E. Mizener, industrial representative; C. M. Hall, Cleveland office manager; T. C. Cornell and W. J. Fenwick, salesmen.

**Blanchard Machine Co., Cambridge, Mass. Booth 256.**

Exhibiting (in operation): No. 16-A automatic surface grinder with automatic sizing device and washing attachment.

In attendance: H. F. Skillings and C. L. Jones.

**Bristol Co., Waterbury, Conn. Booth 33.**

Exhibiting (in operation): Pyrometers and temperature controllers for heat treating furnaces; including indicating pyrometers, recording pyrometers, single record, duplex and six point multiple models, controlling pyrometers with Bristol automatic control valve.

In attendance: H. L. Griggs, general sales manager; C. W. Bristol, chief engineer; R. M. Walker, Pittsburgh-Cleveland district manager; H. W. Moss, Detroit district manager; L. G. Bean, Boston district manager; C. C. Eagle, Philadelphia district manager; H. G. Hall, Chicago district manager; H. E. Bean, Birmingham district manager.

**Brown Instrument Co., Philadelphia, Pa. Booths 65 and 66.**

Exhibiting: New line of Brown recording pyrometers which include single recording, duplex, 6-record multiple, triple duplex (3 records on each of two halves of a duplex chart) and control. An indicating control pyrometer which controls automatically the temperature at two points in a furnace; portable potentiometer, incorporating the unusual 96" scale; the duplex CO<sub>2</sub> and temperature recording meter for checking combustion efficiency in large furnaces; new types of motor operated control valves including valves for controlling oil and air, gas and air, or for controlling furnace dampers. Thermocouples of the latest and thoroughly tested types. Other temperature indicating, recording and control equipment.

In attendance: R. P. Brown, president; G. W. Keller, sales manager; C. L. Simon, technical director of advertising; M. M. Watkins, assistant sales manager; R. W. Mayer, Detroit district manager; G. L. Clapper, Pittsburgh district manager; D. C. Mayne, Columbus district representative; W. E. Woodrow, Pittsburgh district representative.

**Brown Lynch Scott Co., Monmouth, Ill. Booth 120-A.**

Exhibiting (in operation): Perfection compound cleaner and grader.

In attendance: J. A. Scott, secretary and general manager, and W. B. Lynch.

**Brown & Sharpe Mfg. Co., Providence, R. I. Booths 234 and 235.**

Exhibiting (in operation): No. 3 A Universal Milling Machine (Motor-in-Base); No. 33 Automatic Milling Machine; No. 44 Spur and Spiral Gear Hobbing Machine; No. OG Automatic Screw Machine with High Speed Spindle. Precision Tools. This display will include tools representative of the complete Brown & Sharpe Line of over 2000 different tools. Micrometers, Rules, Combination Squares and Sets, Protractors, Bevels, Gages, Indicators, Toolmakers' Tools and Calipers and Dividers will be on exhibition. The tools will be displayed on panels and in a large glass show case. Cutters and hobs. Milling cutters for every requirement will be exhibited, including many special purpose and formed cutters of unusual design. The latest developments in staggered tooth design, interlocking cutters and helical mills will be shown, also, as well as ground form cutters and ground hobs.

In attendance: J. H. Skelton, William Spencer and J. G. Swinburne, salesmen.

**Bullard Machine Tool Co., Bridgeport, Conn. Booths 253.**

Exhibiting: 42" vertical turret lathe.

In attendance: James Welch.

**Bureau of Standards, Washington. Booth 113.**

Exhibiting: Research and testing work illustrated by photographs and special equipment so selected as to indicate fields of co-operation with various industries particularly relating to iron and steel. Attention will be given to current or recently completed investigations; and

there will be available for examination a large number of publications prepared by staff members. Soil corrosion test samples, special rivet steels, tarnish resistant silver alloys, new optical extensometer, etc.  
In attendance: F. J. French, O. Z. Klopsch, T. G. Digges, H. S. Rawdon.

**Campbell, Inc., Andrew C., Bridgeport, Conn. Booth 232.**

Exhibiting (in operation): No. 1 Campbell nibbling machine, belt drive type; No. 1-B Campbell nibbling machine, motor drive; No. 2 Campbell nibbling machine, motor drive. Will cut  $\frac{1}{8}$ ",  $\frac{1}{4}$ ",  $\frac{3}{8}$ ",  $\frac{1}{2}$ ",  $\frac{5}{8}$ " and  $\frac{3}{4}$ " steel on these machines.

In attendance: Stuart Naramore, sales manager; J. Johnson, engineer and demonstrator.

**Carborundum Company, Perth Amboy, N. J. Booth 17.**

Exhibiting (in operation): 1 small gas-fired furnace to show visually the difference in thermal conductivity of various refractory tile in common use. 1 gas-fired furnace to show application of carboradiant chambers for heat treating. Carbofrax tile and brick such as used in common types of heat treating furnaces. Carbofrax and Firefrax high temperature cements.

In attendance: J. A. King, New England sales representative; C. A. Dutton, Detroit and Cleveland representative; R. S. Baker, Chicago representative; S. A. Feno, assistant sales manager.

**Carpenter Steel Company, Reading, Pa. Booth 48.**

Exhibiting: Display of tools made from Stentor Oil Hardening Tool Steel.

In attendance: F. A. Bigelow, president; J. H. Parker, vice president; C. A. Heil, district sales manager; J. N. Clarke, F. W. Curtis, F. G. Davis, V. W. Gardner, sales representatives; F. R. Palmer and W. H. Kemper of the metallurgical department; H. J. Joyce, Jr., sales representative.

**Case Hardening Service Company, Cleveland. Booth 41.**

Exhibiting: Carbonizing compounds; charcoal; bone; cyanide compounds—all grades; Non-Case—anti-carbonizing paint; Cleancoat—covering for lead baths; Drawite—drawing salts of all ranges; Bathite—hardening salts; Hi-Tempo—heat resisting metal; carbonizing boxes; lead and cyanide pots; PresSteel—pressed steel lead and cyanide pots; high temperature furnace cements and all other essential hardening room supplies.

In attendance: W. C. Bell, president; E. J. Gossett, vice president; J. S. Ayling, sales manager.

**Celite Products Company, Los Angeles. Booth 102.**

Exhibiting (in operation): Insulating brick, insulating powder, insulating cement, high temperature cement and water proofing compound for brick surfaces.

In attendance: M. L. Jenkins, sales engineer.

**Central Steel Company, Massillon, Ohio. Booths 51, 52, 67 and 68.**

Exhibiting: General exhibits of special steel products.

In attendance: F. J. Griffiths, president and general manager; B. F. Fairless, vice president in charge of operation; J. M. Schlendorf, vice president in charge of sales; W. M. Garrigues, assistant general manager of sales; D. B. Carson, assistant sales manager; G. F. Hess, sales department; F. L. Gibbons, Cleveland district manager; Arthur Schaeffer, Detroit district sales manager; T. B. Davies, Syracuse sales manager; E. C. Smith, chief metallurgical engineer; C. P. Richter, assistant chief metallurgical engineer; William Leffler, A. J. Wilson, M. Clark and R. K. Bowden, metallurgical engineers.

**Cincinnati Bickford Tool Co., Cincinnati. Booth 257.**

Exhibiting (in operation): 4' radial drill; 20" high speed drill; new 21" direct drive drill.

In attendance: N. C. Schauer, sales manager; R. M. Husband and S. K. Walker, factory representatives.

**Cincinnati Milling Machine Company, Cincinnati. Booth 255.**

Exhibiting (in operation): 8" new design saddle type grinder; No. 3 plain high power milling machine with pyramid column and taper roller bearings throughout; No. 2-M universal with the same features; automatic centerless grinder and a 24" duplex.

In attendance: Walter Tangeman, sales manager; J. E. Caster, L. V. Johnson and Walter Stegner.

**Cincinnati Planer Company, Cincinnati. Booths 252 and 261.**

Exhibiting (in operation): New 36"x36"x8' Hypro planer, with Westinghouse reversing motor drive,—planing steel block, demonstrating advantages of rapid traverse, dial feeds, variable speeds, etc.

In attendance: B. B. Quillen, president; George Langen, works manager; Carl Linden, George Lamoth, and Tom Addison.

**Cincinnati Shaper Company, Cincinnati. Booth 217.**

Exhibiting (in operation): 24" heavy Cincinnati climax shaper, complete with all standard equipment, arranged for motor drive, including 10 HP type SK, G. E. motor, with starter.

In attendance: H. S. Robinson, sales manager; George Diehl, factory demonstrator.

**Cleveland Automatic Machine Company, Cleveland. Booth 233.**

Exhibiting (in operation): CLEVELAND multiple spindle automatic machine.

In attendance: H. W. Ruppel, assistant general manager; H. M. Rich, vice president and treasurer; A. W. Schaffer, sales representative.

**Cleveland Twist Drill Company, Cleveland. Booths 269, 270 and 280.**

Exhibiting (in operation): Three drill presses in operation, demonstrating Cle-Forge high speed drills, brass drills and Peerless high speed reamers.

In attendance: H. G. Smith, Thomas Thomas, F. A. Kelly, R. D. Boltey, F. M. Hoelzle, A. J. Ireland, H. S. White and C. G. Franz, sales representatives; W. E. Caldwell, sales manager; H. P. Jenson, assistant manager of sales; J. B. Dillard, general superintendent; H. J. Baier, chief engineer; D. H. Burdett, assistant to general superintendent.

**Colonial Steel Company, Pittsburgh. Booths 26 and 37.**

Exhibiting: Square split tool steel ingots; square split heat treated alloy, tool steel die blocks; hardened high speed, carbon and alloy tool steel fractures showing various specimens on different degrees of heating. Sample of iron, pure muck bar and all raw materials used in manufacture of high grade tool steel. Pyramid of blocks from 1" to 12" square. Various forgings including oil well bits. Sections of different grades of high speed, carbon and alloy tool steel including plow shapes, section steel, hollow and solid drill steel, safe and jail steel, microscope and a number of polished specimens. Also an electrical display.

In attendance: J. Trautman, Jr., general sales manager; N. B. Hoffman, chemist and metallurgist; F. L. Stevenson, Cleveland district sales manager; Herbert Bray, Chicago district manager; Charles Kopenhoefer, Cincinnati district manager; W. H. Rieger, special representative; Messrs. Hamilton, Hill, Largey and McKinnon.

**Cooper Hewitt Electric Co., Hoboken, N. J. Booth 206.**

Exhibiting (in operation): WORK-LIGHT, the commercial application of mercury vapor lighting in industrial plants. Collection of photographs showing typical installations of WORK-LIGHT, and a special exhibit of installations in the machine tool industry.

In attendance: C. F. Streibig, sales manager; D. R. Grandy, commercial engineer; S. H. Knapp, Cleveland district manager; H. M. Ferree, commercial engineering department.

**Crucible Steel Company of America, New York City. Booths 74, 75 and 76.**  
Exhibiting: Steel and steel products.

In attendance: E. C. Collins, president; Dr. J. A. Mathews, vice president; A. T. Galbraith, general manager of sales; R. Michener, general sales agent; F. E. Phelps, Cleveland district manager; R. C. Webster, Cincinnati district manager; J. W. Taylor and M. S. Dravo of Pittsburgh; B. F. Altman, Cleveland representative; A. H. Kingsbury, special representative.

**Davenport Machine Tool Company, Rochester, N. Y. Booth 250.**

Exhibiting (in operation): Standard five spindle automatic screw machine; also non-stop machine.

In attendance: Messrs. Thomas and Dresser.

**Davison Gas Burner & Welding Co., Pittsburgh. Booth 216.**

Exhibiting (in operation): "A" home oil burner in a hot air furnace; combination oil and gas burner for furnaces and forges, and a line of gas and oil burners for general use.

In attendance: N. C. Davison, president, and Edward Poor, superintendent.

**Dearborn Chemical Co., Chicago. Booth 63.**

Exhibiting: NO-OX-ID chemical rust preventive, and Dearborn cleaners.

In attendance: E. M. Converse, department of specialties; C. I. Loudenback, Detroit representative; E. H. Ruhlman, Cleveland district manager.

**Disston & Sons, Inc., Henry, Philadelphia. Booth 22.**

Exhibiting: Inserted tooth and solid tooth metal cutting saws; metal band saws; hack saws and files; metal cutting products; display of products made from Disston steels.

In attendance: S. H. Disston, vice president; G. Satterthwaite, vice president; D. W. Jenkins, general manager domestic division; Mr. Forrest, manager metal saw department; H. B. Allen, chief metallurgist; J. Dorrington, sales representative; E. Ludy, demonstrator; C. H. Williams, manager of steel works; C. T. Evans, manager steel sales; S. T. Harleman, assistant steel sales manager; Norman Bly, metallurgist.

**Donner Steel Company, Buffalo, N. Y. Booth 93.**

Exhibiting: Various forgings and finished parts made from Donner material.

In attendance: W. F. Vosmer, vice president; F. R. Huston, vice president in charge of operations; J. A. Buell, general superintendent; C. A. Cherry, assistant to vice president; E. D. Pumphrey, Detroit district manager; H. C. Richardson, Cleveland district manager; J. W. Donner, inspection engineer; R. E. Sherlock, metallurgical engineer.

**Driver-Harris Company, Harrison, N. J. Booth 95.**

Exhibiting: Nichrome carburizing pots heated by electric furnace wound with Nichrome ribbon; Nichrome castings for heat treating applications; Nichrome glass roll showing machinability and high finish

attainable; Nichrome cast grids; motor cylinder block of cast iron with small percentage of Nichrome; working exhibit of spark plugs using D-H wire; exhibit of brake band linings using D-H wire; Nichrome retorts; "Cimet" (iron-chrome) castings.

In attendance: G. A. Lennox, assistant general sales manager; W. E. Blythe, Detroit district manager; Messrs. Waldrip, Prior and H. D. Tietz.

**Electro Alloys Co., Elyria, Ohio. Booth 114A.**

Exhibiting: Thermoalloy high temperature heat resisting castings.

In attendance: A. M. Miller, Jr.; E. C. White, W. J. Hansen, R. C. Culver, W. C. Whyte, J. B. Thomas, A. L. Garford and J. W. Henry.

**Electric Furnace Co., Salem, Ohio. Booth 116B.**

Exhibiting: T-Grid electric furnaces for heat treating, annealing, carburizing and enameling. Electric heating equipment for special processes. Sample construction of large furnaces, views of installation, data on operation, etc.

In attendance: R. F. Benzinger, vice president & sales manager; E. T. Cope, chief engineer; F. J. Peterson, Detroit representative; A. H. Vaughn, advertising manager.

**Electrical Refractories Company, East Palestine, Ohio. Booth 120B.**

Exhibiting: Refractories for use in all resistance type electric heating devices; in industrial furnaces, hanger blocks or supports for the support of electric heating elements in stationary industrial furnaces; also muffles and muffle plates, together with terminal supports for small industrial furnaces; also refractories for use in domestic equipment, such as element supports for use in electric ranges, hot plates, fireless cookers and air heaters.

In attendance: F. E. Owen, president; C. W. Williams, secretary and treasurer; F. C. Simms, general manager.

**Engelhard, Inc., Charles, New York City. Booth 53.**

Exhibiting (in operation): Automatic temperature regulators for gas, oil and electric furnaces; Type S and SM recorders in operation on electric resistance thermometers and thermo-electric pyrometers, this is a new development and will be featured. Various types of electric resistance thermometers; base metal thermoelectric pyrometers, rare-metal thermoelectric pyrometers with auxiliary equipment such as switches, tubes, cold end compensators and other fittings. Electric thermal conductivity type gas analyzer for CO<sub>2</sub>, SO<sub>2</sub>, hydrogen, etc.

In attendance: H. DeGallaix, E. S. Newcomb, J. H. Allison and R. W. Newcomb.

**EX-CELL-O Tool & Mfg. Company, Detroit. Booth 287.**

Exhibiting (in operation): XLO standard drill jig bushings; a line of general tools—detailed to manufacturer's specifications; XLO high speed ball bearings (exhibited in connection with the exhibit of the Halcomb Steel Company); XLO high speed internal grinding spindles, featuring the XLO air turbine driven spindle, capable of continuous operation at 65,000 RPM, for grinding of holes  $\frac{3}{8}$ " diameter. Sample bushings with ground holes of this size will be produced. XLO belt driven internal grinding spindles for all grinders.

In attendance: N. A. Woodworth, president and general manager; Clifford Peacock, vice president; Philip A. Huber, secretary; C. R. Alden, manager of sales; W. F. Wise, special representative; E. H. Hopson, service representative.

**Firth Sterling Steel Company, McKeesport, Pa. Booths 14 and 15.**

Exhibiting (in operation): High speed, carbon and alloy tool steels

together with samples of raw materials used and various processes of manufacture.

In attendance: C. O. Ericke, C. E. Hughes, E. T. Jackman, Alan Jackman, D. E. Jackman, Jr., G. A. Jacobs, T. A. Larecy, W. A. Nungester, I. Olsen, W. C. Royce, M. E. Burkemer, Al. Mattson, H. I. Moore, W. A. Ruppel, A. C. Leete, D. G. Clark, Frank Marth.

**Ford Co., J. B., Wyandotte, Mich.** Booth 56.

Exhibiting: Wyandotte cleaning specialties.

In attendance: F. R. Merrick, B. N. Goodell, T. S. Blair, L. C. Warden, C. R. Beaubien, Chief Little Bear.

**Forging-Stamping-Heat Treating, Pittsburgh.** Booth 34A.

Exhibiting: Forging-Stamping-Heat Treating, published by the Andre-sen Company, Inc. Publications devoted to interests of the iron and steel industry will be on exhibit, including Blast Furnace and Steel Plant, Directory of Iron and Steel, Forging, Heat Treating and Stamp-ing Plants.

In attendance: D. L. Mathias, G. P. Grant, F. B. Yeager.

**Ganschow Company, William, Chicago.** Booth 62.

Exhibiting: Ganschow speed reducers, samples of cut gearing and sam-ples of heat treating.

In attendance: C. H. Thomas, sales engineer.

**Gardner Tap & Die Co., Cleveland.** Booth 18.

Exhibiting (in operation): Complete line of taps. One Acme  $\frac{3}{4}$ " six cylinder semi-automatic nut tapper in operation, tapping nuts.

In attendance: J. M. Gardner, president; C. M. Jackson, secretary; H. P. Boggis, sales manager; Fred E. Criley, metallurgist.

**Gathmann Engineering Company, Baltimore.** Booth 107.

Improved quality sound ingots; Gathmann patent ingot molds; Chafin "SLAGO" sink head casings; Gathmann built-up sink head casings; sound ingots of non-ferrous base; photographs of ingot mold-ing; etched sections of ingots and billets; pamphlets descriptive of quality ingot production.

In attendance: Emil Gathmann, vice president and general manager; Mark Gathmann, sales engineer; G. A. Dorning, sales manager.

**General Alloys Company, Boston.** Booths 42 and 58.

Exhibiting: Q-Alloy carburizing boxes, cyanide and lead pots, retorts, muffles, glass dies, conveyor chains, enamel burning racks; ore roast-ing furnace parts, oil-still parts, cyanide dipping baskets, sheet and cast pans and trays, hearth plates, furnace parts, miscellaneous Q-Alloy castings covering the entire heat treating field.

In attendance: H. H. Harris, president; E. P. VanStone, vice president; W. K. Leach, A. L. Grinnell, J. J. Donovan, R. M. Kirk, H. G. Chase, A. D. Heath.

**General Electric Co., Schenectady, N. Y.** Booth 99.

Exhibiting: (In operation): Electric furnaces and automatic electric arc welding.

In attendance: D. G. Brokaw, R. F. Newell, L. B. Rosseau, Walter Anderson, L. A. MacKenney, H. E. Scarborough, C. H. Lockwood, C. L. Ipsen, A. N. Otis, and C. T. McLoughlin.

**Geometric Tool Company, New Haven, Conn. Booth 233.**

Exhibiting (in operation): Self-opening and adjustable die heads; self-opening and adjustable rotary die heads; solid adjustable die heads; adjustable collapsing taps; adjustable collapsing rotary taps; solid adjustable taps; Geometric chaser grinder; Geometric threading machine; tapping machine; adjustable hollow milling tools; Jarvis high speed tapping devices; Jarvis friction drive tapping devices; Jarvis quick change chucks and collets; Jarvis self-opening stud setter.

In attendance: E. W. Mertz, E. J. Gillis, F. W. Gowrie, F. A. Barker, E. L. Wood, metallurgist; G. A. Denison, sales manager.

**Giddings & Lewis Machine Tool Co., Fond du Lac, Wis. Booth 245.**

Exhibiting (in operation): Theromatic, grinding roller bearing cones; No. 45 horizontal boring, drilling and milling machine with 12" high column and 2' extra length bed.

In attendance: Messrs. Kraut and Gebuhr.

**Gisholt Machine Company, Madison, Wis. Booth 223A.**

Exhibiting (in operation): New Gisholt 3L all steel geared head turret lathe with new features of design. Gisholt 4B universal turret lathe. Gisholt precision balancing machine for rotative parts.

In attendance: E. S. Chapman and C. B. Carr.

**Goddard & Goddard Company, Detroit. Booth 90.**

Exhibiting: High production milling cutters, both standard and special, including slab mills, channelling cutters, locomotive taper reamers and helical mills, such as used in railroad shops.

In attendance: A. N. Goddard, president; C. H. Wallace, railroad demonstrator; R. T. Rice, E. E. Toerner, E. E. Guntert, C. S. Goddard, sales manager.

**Goss & DeLeeuw Machine Company, New Britain, Conn. Booth 266B.**

Exhibiting (in operation): Four spindle automatic chucking machine.

In attendance: S. T. Goss, president; J. J. Spring, sales engineer; E. H. Peck, manager of service and demonstration.

**Gould & Eberhardt, Inc., Newark, N. J. Booth 247.**

Exhibiting (in operation): 32" Invincible type shaper, operating on die blocks; No. 16-HS Hobber cutting Chandler transmission gears.

In attendance: Fred Eberhardt, president; H. W. Jacobson and G. H. Davis.

**Gray Co., G. A., Cincinnati. Booth 237.**

Exhibiting (in operation): Gray maximum service planer 36"x36"x10', with reliance Cutler-Hammer reversing motor drive. Equipped with helical gear train, all of steel and running in oil. Single shift rapid traverse, cantslip positive dial feed, Gray rail-lock and rail-setter. Automatic lubrication with filtered oil to V's and drive shaft bearings, centralized control, and centralized lubrication of rail parts. Heads to have twin-purpose taper gibs and abutment tool aprons. Many of these features are patented, and the head design has never been exhibited before.

In attendance: August Marx, president and general manager; F. E. Cardullo, chief engineer; Tell Berna, sales manager; Philip Leisinger, planer superintendent.

**Hagan Company, George J., Pittsburgh. Booth 13.**

Exhibiting (in operation): Installation of a full automatic rotary furnace for handling small regular shaped pieces on a production basis.

Materials to be heated will be charged into and discharged from the furnace automatically, the rotating hearth stops and starts automatically and the temperature is controlled automatically. All materials discharged from the furnace pass directly from furnace to the quenching medium without coming into contact with the air. The furnace is suited for operating direct on 220 volts D. C., or single phase A. C. and 110 volts, three phase A. C. Also, complete photographic display of a great number of operating installations of practically every type of electric heating furnace, together with operating data.

In attendance: R. E. Talley, president; H. G. Hammer, treasurer; J. Sandberg, Detroit district manager; V. A. Hain, Chicago district manager; C. F. Cone, J. L. Edwards and A. D. Dauch.

**Halcomb Steel Company, Syracuse, N. Y. Booths 85 and 86.**

Exhibiting: Tools made from carbon, special and high speed steels; automotive and special engineering parts made from Halcetralloy brand steels; parts made from non-corrosive steels.

In attendance: H. J. Stagg, assistant manager; M. P. Spencer, assistant sales manager; J. H. Hinkley, Chicago district manager; J. F. Kirwan, Cleveland district manager; Arthur Schroeder, Detroit district manager; T. F. Wood, Syracuse district manager; F. W. Ross, New York district manager; S. C. Spalding, metallurgist; J. T. Leyden, J. H. Schnibbe and E. F. Talmage.

**Hammond Mfg. Co., Cleveland. Booth 212.**

Exhibiting (In operation): 1 eight spindle automatic deep hole drilling machine, motor driven. 1 Radial stud driver and nut setter, motor driven 1 column and base radial drilling machine, with friction tapping attachment, motor driven. 1 cabinet base motor driven polishing and buffing machine.

In attendance: C. M. Allen, president; W. D. Buss, manager and superintendent.

**Hanson-Whitney Machine Company, Hartford, Conn. Booth 282.**

Exhibiting (in operation): Universal semi-automatic thread milling machine; universal vertical tool and die shaping machine; universal tap sharpening machine; taps, gages, precision screws, thread rolling dies (flat and circular) and hobs,—all finished after hardening by the "Hanson process."

In attendance: E. A. Hanson, engineer; C. A. Lauridsen, demonstrator; J. W. Johnson, engineer.

**Heald Machine Company, Worcester, Mass. Booths 267 and 268.**

Exhibiting (in operation): Style No. 72 full automatic internal grinding machine, arranged for self contained full motor drive (grinding the bores of ball bearing races). Style No. 72 semi-automatic internal grinding machine, arranged for self contained full motor drive (grinding bores of collars). Style No. 25 full automatic down feed surface grinding machine, arranged for self contained motor drive (face grinding ball bearing races).

In attendance: J. N. Heald, general manager; S. T. Massey, sales manager; R. M. Lippard, Cleveland district manager; R. A. St. John, sales engineer; F. H. Grimshaw, sales engineer.

**Heim Grinder Company, Danbury, Conn. Booth 215.**

Exhibiting (in operation): Heim centerless cylindrical grinding machine equipped with full automatic attachment and motor driven, together

with all necessary equipment for handling through and shoulder grinding.

In attendance: F. M. Angevin, general manager; C. Booth, works manager; R. Krametz and C. Previdi.

**Heppenstall Forge & Knife Company, Pittsburgh.** Booth 106.

Exhibiting: An enameled and nickel plated surface die block.

In attendance: G. I. Allen, F. C. Moyer, G. O. Desautels, C. W. Heppenstall, E. O. Jenkins.

**Hevi-Duty Electric Co., Milwaukee.** Booth 23.

Exhibiting (in operation): One HD 14368 Radiant type tool room furnace, 14" wide, 36" long, 8" high. One HD 142412 Oil bath, 14" wide, 24" long, 12" deep. One Hevi-Duty crucible furnace 15" diameter, 30" deep. One HD-70-S Radiant type tube furnace, 1 1/4" inside diameter, 18" long.

In attendance: E. A. Hansen, manager of sales; Edward Busch, Cleveland district manager; F. A. Weiser, chief engineer; and others.

**Holcroft & Company, Detroit.** Booth 16.

Exhibiting: Photographs, drawings and data on heat treating furnaces, melting furnaces and continuous kilns.

In attendance: C. T. Holcroft, president; H. L. Ritts, secretary-treasurer; Alfred Ruckstahl, engineer.

**Hoskins Mfg. Company, Detroit.** Booth 98.

Exhibiting (in operation): Electric tool room furnace equipped with automatic temperature control. Hoskins pyrometer and chromel thermocouples. Display board of Hoskins-Chromel resistor alloys.

In attendance: W. D. Little, sales manager; C. S. Kinnison, advertising manager; W. A. Gatward, chief engineer; J. D. Sterling, Cleveland district manager.

**Houghton & Co., E. F., Philadelphia, Pa.** Booth 54 and 55.

Exhibiting: Heat treating materials, Vim leather belting and Vim leather packings. Electric pots for liquid heat and drawing temperature.

In attendance: H. G. Lloyd, H. E. Cressman, W. J. Wright, Robert Smith, W. A. Buechner, J. C. Bentley, F. L. Machamara, W. A. Fletcher, I. D. Fletcher, D. D. Reed and E. C. Redlin.

**International Machine Tool Co., Indianapolis.** Booth 215.

Exhibiting (in operation): 26x7 1/2" bore LIBBY-INTERNATIONAL turret lathe on railroad work.

In attendance: D. J. Cosner, special Cleveland representative.

**International Nickel Company, New York City.** Booths 78 and 89.

Exhibiting: Collections of parts made from nickel steel,—such as nickel steel castings and forgings, automotive and aeroplane parts; tools, such as saws, chisels, etc.; die blocks; roller bearings; gears; steel mill rolls; turbine blades; and some castings of nickel cast iron.

In attendance: A. J. Wadhams, manager of development and research department; Dr. P. D. Merica, director of research; Charles McKnight, Jr., T. H. Wickenden and J. S. Vanick of the development and research department; L. Muller Thyn and R. A. Wheeler of the sales department.

**Interstate Iron & Steel Co., Chicago.** Booth 108.

Exhibiting: Samples of raw and forged steel from ingots to finished forgings as well as photographic views of heat treatment and physical

elements tending to show progress during the year in production of sound steel.

In attendance: Paul Llewellyn, vice president; W. H. C. Carhart and Elmer Larned of Chicago; John A. Guyer of Cleveland, and R. S. LeBarre of Detroit, W. J. MacKenzie Chicago office.

**Iron Age Publishing Co., New York. Booth 83.**

Exhibiting: Iron Age current issues, and reprints of special sections.

In attendance: W. W. Macon, E. F. Cone, R. E. Miller, F. L. Prentiss, G. L. Lacher, F. J. Frank, H. E. Barr, E. Findley, D. G. Gardner, B. L. Herman, Pierce Lewis, Chas. Lundberg, C. L. Rice, W. B. Robinson, F. W. Schultz, E. Sipnock, W. C. Sweetser, D. C. Warren, F. S. Wayne, C. S. Baur.

**Jessop Steel Company, Washington, Pa. Booth 119.**

Exhibiting: Finished products manufactured from Jessop's high grade tool steels. Swedish iron exhibit—and other raw materials.

In attendance: V. M. Wellman, Cleveland manager; R. K. Greaves, Detroit district manager; V. H. Lawrence, metallurgist; J. M. Curley, Boston representative; C. R. Trimmer, Chicago representative; E. V. Vogeley, New York manager; and W. J. Fredericks, Cincinnati representative.

**Jones & Lamson Machine Company, Springfield, Vt. Booths 229 and 230.**

Exhibiting (in operation): Hartness flat turret lathe—15" chucking machine turning drop forged steel adjusting collar. Hartness flat turret lathe—2¼x24" bar machine turning cap screws. Hartness screw thread comparator gaging cap screws. Hartness automatic die head—"High Speed" series, threading cap screws. Fay automatic lathe—machining second operation automobile ring bevel gear. Flanders ground thread taps.

In attendance: H. S. Beal, assistant general manager; C. H. Seaver, Cleveland district manager; F. L. Watkins, Detroit representative; J. L. Reilly, Indianapolis representative.

**Jones & Laughlin Steel Corporation, Pittsburgh. Booth 79.**

Exhibiting: Various products of interest.

In attendance: A. A. Wagner, assistant manager sales of hot rolled department; E. A. France, Cleveland district manager; J. G. Hutchinson, S. A. Fuller, and others.

**Kardex-Rand Company, Tonawanda, N. Y. Booth in Lobby.**

Exhibiting: All types of visible record equipment, the merger lines of Kardex Co., Rand Co., and Index Visible Co.

In attendance: W. C. Mowry, Cleveland district manager; A. H. Fritchman, S. S. Shane, P. A. Eaton, J. H. Mahrer, L. Blueck, I. M. Stubbart, A. T. Hoover.

**Keller Mechanical Engineering Corporation, Brooklyn, N. Y. Booth 248.**

Exhibiting (in operation): BL Keller all-round die tool and pattern room machine. R-6 Keller cutter and radius grinder—improved. BK-3 Keller roller floor stand flexible shaft grinder. BK-1 Keller bench stand flexible shaft grinder.

In attendance: Jules Diereckx, vice president and sales manager; A. J. Benson, P. Brown and Charles Bitter.

**Kelly Reamer Company, Cleveland. Booth 284.**

Exhibiting: Block unit adjustable boring and reaming tools; multiple bladed adjustable boring and reaming tools; single point boring bars;

hardened and ground bars; strip piloted bars; mandrels and arbors; Kelly production tools.

In attendance: E. W. Putnam, general manager; M. C. Daw, chief engineer; A. H. Howard, sales representative.

**Keystone Lubricating Company, Philadelphia.** Booth 88.

Exhibiting (in operation): Keystone safety lubricating system as applied to machinery bearings, and rubber hose leads connected to moving bearings. Samples of various densities of Keystone grease for all mechanical conditions.

In attendance: Peter Cassidy, Western manager; V. Berguson, M. C. Schwenk, F. D. Street.

**King Machine Tool Co., Cincinnati.** Booth 236.

Exhibiting (in operation): One 42" gear box motor driven boring mill.

In attendance: E. A. Muller, vice president.

**King Refractories Company, Niagara Falls, N. Y.** Booth 19.

Exhibiting (in operation): High temperature cements and "MONO" baffles. One Balopticon machine; advertising literature and samples of cements.

In attendance: S. C. Smith, president; F. A. Podwils, Cleveland representative.

**Knight Machinery Co., W. B., St. Louis,** Booth 214.

Exhibiting (in operation): No. 3 Knight Miller, complete with full equipment, with high speed, horizontal milling and shaping attachments for use with machine. A large variety of sample work done on Knight millers.

In attendance: W. B. Knight, Jr.

**Kearney & Trecker Corporation, Milwaukee.** Booth 205.

Exhibiting (in operation): No. 28 Plain MILWAUKEE milling machine, —new style external motor drive,—equipped with a special production service reciprocating fixture, for milling clutch teeth in small bevel gears. Rate of production—175 to 200 pcs. per hour. No. 1B vertical MILWAUKEE milling machine. Latest style motor-in-base drive, equipped with special production service rotary fixture, for milling slots 2000 pcs. per hour in wrist pin set screws,—courtesy of Ajax Motors, Racine.

In attendance: Theodore Trecker, president; E. J. Kearney, secretary and treasurer; J. B. Armitage, chief engineer; Joseph Trecker, production department; W. K. Andrew, production service department; G. L. Erwin, Jr., sales department; R. A. Wellington, Cleveland branch manager; and Clarence Hochmuth.

**Landis Tool Co., Waynesboro, Pa.** Booths 293 and 294.

Exhibiting (in operation): Crank grinding machines for grinding crankshafts of automobiles. Internal grinding machine with hydraulic traverse, 10"x36" hydraulic traverse plain grinding machine, 6"x20" hydraulic traverse plain grinding machine.

In attendance: J. S. Baker, Cleveland representative; I. S. Deardorff, Cleveland representative; F. Griner and C. M. Talhelm, Detroit representative; W. G. Nevin, sales manager.

**Leeds & Northrup Company, Philadelphia.** Booth 10.

Exhibiting (in operation): New circulating air drawing furnaces; Hump furnaces for small tools and furnaces for drop forge dies. Recording and indicating pyrometers. Automatic temperature controllers and miscellaneous instruments applying to steel treating.

In attendance: G. W. Tall, Jr., assistant sales manager; A. E. Tarr, district manager; Henry Brewer, assistant sales manager; E. B. Estabrook, district manager; O. Brewer, P. H. Taylor, A. F. Moranty, H. R. Abey, C. C. Graf, W. A. Lane, T. C. Smith, Jordan Korp and J. P. Docherty.

**Lehmann Machine Company, St. Louis. Booth 285.**

Exhibiting (in operation): One 22-24- $\frac{1}{2}$ "x1' bed (taking 6' between centers) "LEHMANN SIXTEEN SPEED GEARED HEAD ENGINE LATHE" motor driven, complete with standard equipment and with improved taper attachment fitted. 16" "LEHMANN" improved sixteen speed geared headstock with cover removed and 1 24" "LEHMANN" improved hardened lathe spindle with patented nose giving double bearing for chuck and face plates.

In attendance: Paul Lehmann, president.

**Leitz, Inc., E., New York City. Booth 35.**

Exhibiting (in operation): Micro-Metallograph of latest design, Model 1925, embodying new features and improvements never before shown in any previous model. Specimens will be prepared and photographed at 10,500 diameters, which represents the highest magnification as yet obtained. New grinding and polishing machines for metal specimens. A low power magnifier for use in steel and metal plants for visual examination of fractures and flaws. Ore dressing microscope.

In attendance: Messrs. Ziegler and Vollrath.

**Leland-Gifford Company, Worcester, Mass. Booth 204.**

Exhibiting (in operation): No. 1 12" 1-sp. floor type motor spindle ball bearing drilling machine. No. 1 12" 2-sp. floor type belt drive ball bearing machine with motor mounted on rear of machine, with power feed on 1 spindle, No. 1 ball bearing tapper on second spindle. No. 2 14" 1-sp. motor spindle drilling machine. No. 2 14" 3-sp. belt drive drilling machine with motor mounted on rear of column, complete with power feed and tapping attachment. No. 3 24" 1-sp. belt drive ball bearing drilling machine, with motor mounted on rear of column, complete with power feed. No. 2 EM Washburn Shops drill grinder.

In attendance: S. Nikoloff, vice president; S. B. Dowd, sales manager; A. H. Anderson, Cleveland manager; E. A. Heidlinger, Detroit manager.

**Liberty Machine Tool Company, Hamilton, Ohio. Booths 218 and 219.**

Exhibiting (in operation): One 36"x36"x10' two housing late model Liberty planer, to be equipped for reversing motor drive with motor mounted on the floor and connected to driving shaft through a Grundy coupling. Planer to be equipped with two rail heads and two side heads employing individual motors to each side head for power rapid traversing vertically and to rail head for control of power rapid traverse as well as elevating or lowering of rail.

In attendance: A. R. McCann, vice president and general manager; A. Iutzig, general superintendent; J. Milliken, purchasing agent.

**Lodge & Shipley Machine Tool Company, Cincinnati. Booth 260.**

Exhibiting (in operation): Duomatic operating on Chandler cluster gears. 14" selective head tool room lathe.

In attendance: Fred Albrecht, sales manager, and J. M. Stephens.

**Lucas Machine Tool Company, Cleveland. Booth 242.**

Exhibiting (in operation): "PRECISION" horizontal boring, drilling and milling machine. LUCAS power forcing press.

In attendance: F. P. Sprague, sales representative, and J. A. Leighton, sales representative.

**Ludlum Steel Company, Watervliet, N. Y. Booths 29 and 30.**

Exhibiting: Tool steels,—carbon and alloy, high speed, special alloy, rust and strain resisting steels and iron, heat resisting steels and non-corrosive steels. Showing methods of producing these steels and representative tools made therefrom.

In attendance: H. G. Batcheller, vice president and general sales manager; W. H. Vrooman, assistant manager of sales; C. B. Templeton, sales department; A. K. Martin, superintendent; R. P. DeVries, metallurgist; W. H. Keen, W. J. Fitzgerald, metallurgical department; W. L. Weaver, Albany district manager; T. C. Sherman, Cleveland district manager; P. R. Thurston, W. Kinsey of Cleveland district; J. E. Polhemus, Detroit district manager; H. W. Spiegel, H. I. Askew, Jr., and J. J. Cruice, Detroit representatives.

**Marschke Mfg. Company, Indianapolis. Booth 292.**

Exhibiting (in operation): One 20" heavy duty grinder and one 12" general duty grinder,—each machine fully equipped and with latest design wheel guards of two types.

In attendance: W. A. Marschke, vice president and sales manager.

**Midvale Company, Nicetown, Philadelphia, Pa. Booth 77.**

Exhibiting: Diesel engine crankshaft, brass extrusion cam; forged and hardened rolls for cold rolling; tools manufactured from Midvale tool steels; hammer piston rod.

In attendance: Stuart Hazlewood, H. H. Ziesing and H. E. Rowe of Philadelphia; W. A. Miller, New York; F. W. Sager, Chicago; Harry Teel, Detroit; and T. G. Besom of New York.

**Monarch Machine Tool Company, Sidney, Ohio. Booth 207.**

Exhibiting: One 9x3 Monarch Junior lathe; one 14x6 helical geared head, tool room lathe; one 18x6 helical geared head manufacturing lathe; one 22x12 helical geared head engine lathe,—all machines arranged for individual motor drive.

In attendance: W. E. Whipp, secretary and treasurer; J. A. Raterman, sales engineer.

**Morris Machine Tool Company, Cincinnati. Booth 286.**

Exhibiting (in operation): One MORRIS 3' heavy duty radial drill arranged for variable speed motor drive.

In attendance: E. G. Meckstroth, superintendent; A. C. Pletz, general manager.

**Morse Twist Drill & Machine Co., New Bedford, Mass. Booth 82.**

Exhibiting: Samples of various tools, consisting of drills, reamers, taps and dies, and milling cutters,—both in high speed and carbon steel, also special tools for special work. No. 2 universal grinder—not in operation.

In attendance: W. T. Read, vice president and treasurer; F. O. Lincoln, vice president in charge of sales; W. F. Congdon, Detroit manager; M. G. Bonner and R. W. Mein, sales representatives.

**Motch & Merryweather Machinery Company, Cleveland.** Booths 244 to 261, inclusive.

**Exhibiting (in operation):** Machine Tools manufactured by the following firms:

Abrasive Machine Tool Company  
Acme Machine Tool Company  
Badger Tool Company  
Baker Brothers  
Blanchard Machine Company  
Bullard Machine Tool Company  
Cincinnati Bickford Company  
Cincinnati Milling Machine Company  
Cincinnati Planer Company  
Davenport Machine Tool Company  
Avey Drilling Machine Company  
Giddings & Lewis Machine Tool Company  
Gould & Eberhardt, Inc.  
Keller Mechanical Engineering Corporation  
National Equipment Company  
Lodge & Shipley Machine Tool Company  
Thompson Grinder Company  
Production Machine Company  
V & O Press Company

**In attendance:** From Cleveland—G. E. Merryweather, president; E. R. Motch, secretary; E. R. Motch, Jr., R. J. Houck, J. S. Phelps, W. F. Wissman, W. F. Hall, A. B. Einig, W. F. Gallen and R. G. Knapp. From Cincinnati—E. A. Shriver, manager; M. H. Dones and L. C. Lobitz. From Pittsburgh—E. C. Batchelar, manager; J. T. McCuen, L. A. Rafferty, J. A. Menges, L. C. Deckard, J. L. Vance. From Detroit—R. C. Handloser, manager; E. F. Lickey, E. A. Guntrum, H. C. Bayliss, J. F. Dittus, V. Gottsman, N. H. Carpenter.

**National Automatic Tool Company, Richmond, Ind.** Booths 228 and 238.

**Exhibiting (in operation):** One Garvin No. 2SS horizontal duplex driller; No. C-13-A NATCO driller; No. C-13-A NATCO tapper; No. A-103 NATCO continuous driller; No. 9 NATCO Minster Hi-Duty driller. An exhibit of NATCO universal joints and tool holders.

**In attendance:** F. A. Root, assistant sales manager.

**National Electric Light Association, New York City.** Booth 110.

Photographs and engineering data on industrial heating installations. Those in attendance in booth will endeavor to give information and advice on industrial heating installations.

**In attendance:** Various representatives of industrial heating firms.

**National Equipment Co., Springfield, Mass.** Booth 259.

**Exhibiting:** New Type NB forging and riveting machine; NC machine, also.

**In attendance:** A. L. Bausman, G. A. Bausman, Joel Whitney, Charles Gowing, John Peterson.

**National Twist Drill & Tool Co., Detroit.** Booths 265 and 275.

**Exhibiting (in operation):** Display of drills, reamers, cutters, hobs and special tools, also parabolic milling cutters in operation.

**In attendance:** Harry Butler, C. Cornwall and G. Webster, sales representatives.

**New Britain Machine Company, New Britain, Conn.** Booths 239 and 240.

**Exhibiting (in operation):** No. 12A New Britain tool rotating chucking

machine. No. 452 New Britain New-Matic chucking machine. No. 204 New Britain six spindle automatic screw machine.

In attendance: H. H. Pease, president; E. L. Steinle, manager machinery sales; G. K. Atkinson, Ohio representative; T. C. Stirling, Detroit representative; H. L. Wilson, Chicago representative; C. L. Perry, C. Hanson and S. Mayerjack.

**Norton Company, Worcester, Mass.** Booths 231 and 241.

Exhibiting (in operation): Norton cylindrical grinding machine, and a display of grinding wheels; Norton floor products,—consisting of Alundun floor and stair tile and treads; Norton refractories.

In attendance: O. E. Nordstrom, district manager; Erick Hellstrom, O. A. Knight, district manager; C. H. Hill, district representative; W. T. Montague, sales manager; H. J. Griffing, assistant sales manager; H. W. Dunbar, assistant general sales manager.

**Nuttall Company, R. D., Pittsburgh.** Booth 59.

Exhibiting: Gears and pinions for various applications, that have been heat treated and hardened by our BP process, including such gears as used on trunk line electric locomotives, rolling mill table mitre driver; our single helical rolled steel gears for traveling cranes, and several items of gearing and other wearable mill parts that have been in service to show their performance record.

In attendance: Q. W. Hershey, sales manager; J. E. Mullen; W. H. Phillips, manager engineering and works; R. W. Young, sales engineer; W. H. Smith, sales engineer, and C. H. Parker.

**Oesterlein Machine Co., Cincinnati.** Booth 289.

Exhibiting (in operation): One No. 2 motor driven constant speed "Ohio" milling machine. One No. 2 motor driven universal and tool grinder.

In attendance: G. M. Meyneke.

**Ohio Steel Foundry Co., Springfield, Ohio.** Booth 38.

Exhibiting: Fahrite heat resisting alloy castings,—annealing boxes, hearth plates, support beams, furnace rails, carbonizing boxes, discs, for continuous conveyor furnaces, and miscellaneous castings for use in high temperature work.

In attendance: T. H. Harvey, vice president; C. E. Malley, alloy division.

**Oilgear Company, The, Milwaukee.** Booth 226.

Exhibiting (in operation): 10 ton Oilgear semi-automatic broaching and assembling press.

In attendance: Donald Clute and Harold Crull.

**O. K. Tool Company, Shelton, Conn.** Booth 276.

Exhibiting (in operation): Universal grinding machine with special designed OK attachment for regrinding inserted tooth sectional hobs. This fixture can also be used for grinding any style milling cutter by simply releasing the gear drive. It can be attached to any universal machine. A motor driven grinding machine with special fixture attached for grinding OK tools. A complete assortment of standard sets, also OK sets for special purpose machines.

In attendance: F. J. Wilson, secretary; R. R. Weddell, engineer; R. S. Young, metallurgist; Frederick Schroeder, sales representative.

**Oliver Instrument Company, Adrian, Mich.** Booth 227.

Exhibiting (in operation): Oliver automatic drill pointer; Oliver point thinner, and Oliver die making machine.

In attendance: E. C. Oliver, manager.

**Olsen Testing Machine Co., Tinius, Philadelphia. Booth 43.**

Exhibiting (in operation): Various types of testing machines, including Olsen Universal testing machine with various attachments. Various types of Brinell hardness testing machines, and Olsen Last Word hardness testers. Extensometers, strain gages and elongation scale for use in tension and compression testing. Latest type of motor driven ductility testing machine for sheet metal. Olsen-Lundgren crankshaft and fly wheel balancing equipment for correcting static and dynamic unbalance of rotating parts.

In attendance: Jacob Lundgren and W. J. Tretch.

**Oxweld Acetylene Company, New York City. Booth 101.**

Exhibiting: Oxweld apparatus; Linde Oxygen Prest-O-Lite Acetylene and Union Carbide. Welds will be made, cut into coupons by an Oxy-acetylene straight line blowpipe, and tested with a universal testing machine, showing the strength of the welded union.

In attendance: E. E. Thum, publicity department; J. W. Dunn; J. P. Dawson, Union Carbide and Carbon research laboratories; J. V. Upton and H. H. Dyar.

**Park Chemical Company, Detroit. Booth 111.**

Exhibiting: Case hardening compounds; cyanide mixtures; drawing salts and other heat treating materials.

In attendance: J. N. Bourg, D. W. Bauer and F. W. Faery.

**Peerless Machine Company, Racine, Wis. Booth 12.**

Exhibiting (in operation): High speed power hacksawing machinery,—motor driven 9"x9" standard Peerless type, motor driven 6"x6" standard Peerless type,—motor driven 9"x9" universal type.

In attendance: R. T. Ingalls, sales manager; A. H. Goetz, field representative; Charles Rasmussen, mechanical engineer.

**Pels & Co., Henry, New York City. Booth 291.**

Exhibiting (in operation): Two triple combined punching and shearing machines—one small and one large; that will punch holes in steel, cut angles, tees, bars and plate,—without changing tools. One shearing machine for cutting angles, tees, beams and channels.

In attendance: T. C. Sternblad, secretary.

**The Penton Publishing Company, Cleveland. Booth 40.**

Exhibiting: Technical and commercial periodicals and books dealing with heat treating, forging, etc.

In attendance: C. J. Stark, editor, Iron Trade Review; Earl Shaner, managing editor, Iron Trade Review; E. F. Ross, associate editor; J. D. Pease, advertising manager; John Henry, Max Reimer and G. P. Howarth, all of advertising department; F. V. Cole, circulation manager; F. F. Light, assistant circulation manager.

**Pittsburgh Crucible Steel Co., Pittsburgh. Booth 87.**

Exhibiting: Forging grades of steel,—photographs and charts showing samples of products.

In attendance: F. B. Hufnagel, president; R. M. Keeney, general superintendent; A. H. Sonnhalter, assistant general superintendent; O. L. Pringle, superintendent of metallurgical and inspection department; S. D. Williams, superintendent of open hearth; W. I. McInerney, superintendent of heat treating and cold drawing departments; E. T. Walton, chief inspector; W. E. Davis, W. P. Benter and W. R. Howell, metallurgists; W. W. Williams, general sales manager; K. E. Porter.

assistant general sales manager; J. N. Critchlow, Detroit sales manager; T. A. Goodridge, Cleveland sales manager; H. T. Harrison, B. B. Holt and Myron Powers, salesmen.

**Pittsburgh Instrument & Machine Company, Pittsburgh. Booth 103.**

Exhibiting (in operation): Brinell hardness testing machines, including microscopes and depth gages; impact testing machine; metal sheet tester; metallographic grinder and Buvinger's weight calculating instrument for use of car wheel manufacturers.

In attendance: Paul Kammerer and Charles Trueg, proprietors.

**Potter & Johnston Machine Company, Pawtucket, R. I. Booth 223B.**

Exhibiting (in operation): 6-C automatic chucking machine; Unimatic machines; 2-M automatic milling machine and a 24" universal shaping machine.

In attendance: N. R. Earle, general manager of sales.

**Pratt & Whitney Company, Hartford, Conn. Booths 277 and 278.**

Exhibiting (in operation): Machine tools; 6" shaper; 13"x30" Model "B" lathe; automatic centering machine; double bench outfit, with lathe; universal milling machine and drill press; supermicrometer. Small tools and gages: Display board on which are mounted taps and dies, cutters, reamers, hobs, gages. A special display board of tools that have made record runs.

In attendance: W. P. Kirk, sales manager; A. E. R. Turner, Cleveland district manager; J. J. Heber and G. E. Thomas, Cleveland office; E. C. Shultz, publishing director; E. J. Sullivan, special representative; A. H. d'Arcambal, metallurgist and sales engineer.

**Production Machine Company, Greenfield, Mass. Booth 251.**

Exhibiting (in operation): Type "A" cylindrical polishing machine. Type "F" polishing machine for flat work. Type "R" combined disc grinder and polishing machine.

In attendance: A. H. Behnke, sales manager; and Mr. Fuller.

**Republic Flow Meters Company, Chicago. Booths 69 and 70.**

Exhibiting (in operation): Indicating and recording pyrometers with complete accessories. Combustion instruments consisting of CO<sub>2</sub> boiler meters, etc.—draft instruments, flow meters, etc.

In attendance: J. S. Cunningham, president; C. C. McDermott, pyrometer division; G. V. Nightingale, Philadelphia office; M. E. VanVliet, Pittsburgh office; A. M. Steever, Detroit office; F. A. Hall, New York office; and D. J. Jones of Chicago.

**Rockwell Co., W. S., New York City. Booth 61.**

Exhibiting: Models of operating furnaces.

In attendance: J. N. Voltman and C. D. Barnhart.

**Rockford Machine Tool Company, Rockford, Ill. Booth 287.**

Exhibiting (in operation): 24" mechanics production drill press. 24" Rockford improved variable speed motor.

In attendance: M. Monson, superintendent; and W. K. Stamets.

**Rockford Milling Machine Company, Rockford, Ill. Booth 266A.**

Exhibiting (in operation): Rockford rigid mill, completely equipped with motor drive and cutters. Sundstrand stub lathe, completely equipped with motor drive and tooled for production on automotive parts.

In attendance: C. B. DeVlieg and G. A. Markuson.

**Rodman Chemical Company, Verona, Pa. Booth 84.**

Exhibiting: Carburizing materials; quenching oils; tempering oils; luting clay.

In attendance: Hugh Rodman, president; G. A. Webb, Detroit district manager; S. P. Rockwell, New England representative; W. D. Fuller, New England representative, and O. T. Muehlemeyer, Rockford, Ill., representative.

**Roessler & Hasslacher Chemical Company, New York City. Booth 44.**

Exhibiting: Cyanegg sodium cyanide 96.8%; Cyanogram sodium cyanide 96.8%; R & H case hardener granulated 30%; R & H case hardener—slabs 30%; R & H special case hardener—slabs 45%. Cyanide chloride mixture sodium cyanide 73.6%. A complete line of chemicals. Also a demonstration of electro plating of steel with zinc and copper and the case hardening of steel with cyanide.

In attendance: W. M. Gager and C. H. Proctor, and also representatives from Cleveland district.

**Sebastian Lathe Company, Cincinnati. Booth 290.**

Exhibiting (in operation): One 15x6 geared head motor driven lathe.

In attendance: E. E. Stokes, president.

**Seneca Falls Machine Company, Seneca Falls, N. Y. Booth 295.**

Exhibiting (in operation): Seneca Falls cost cutting turning equipment. "LO-SWINGS," plain and semi-automatic. "SHORT-CUT" production lathes. "STAR" screw cutting engine lathes.

In attendance: E. R. Smith, vice president and general manager; J. A. Fyfe, secretary; W. H. Nettle, Midwest representative; F. B. Webb and M. C. Day, sales engineers; G. J. Hawkey.

**Shore Instrument & Mfg. Company, New York City. Booth 34B.**

Exhibiting: Standard model C-1 scleroscope, ball type. Standard model D scleroscope, dial type. Special heavy model C-1 scleroscope on D-type clamp. Electric actuator for C type in operation. Tilting table with fixtures. Types "A" and "B" PYROSCOPES 1200-3000 degrees Fahr. Localcase (control carbon in carburizing). Localhard (control hardness in tool steel). Durometer for measuring hardness of plastic material,—as rubber. Elastometer for measuring elasticity of plastic material. Jiggs and fixtures.

In attendance: F. G. Kendall, sales manager.

**Simonds Saw & Steel Co., Fitchburg, Mass. Booths 72 and 73.**

Exhibiting: Metal cutting-off saws both solid and inserted tooth. Metal slitting saws; screw slotters; files; hack saw blades; tool holder bits; carbon and high speed steel machine knives; and wood cutting saws. Tool steels; permanent magnet steels; chisel steels; chromium ball and bearing steels; bar and sheet steels.

In attendance: G. T. Curtis, H. B. McDonald and H. D. Weed.

**The Skinner Chuck Company, New Britain, Conn. Booth 92.**

Exhibiting (in operation): Lathe, drill and planer chucks. A small bench lathe for the purpose of demonstrating the accuracy of Skinner chucks. Cut open models showing operating mechanism of various types of lathe chucks. Skinner box body 2-jaw lathe chucks (a chuck of new design having several unique features). Air operated chucks with the new type of cylindrical jaw.

In attendance: Wm. H. Day, assistant treasurer.

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**Skybryte Company, Cleveland. Booth 109.**

Exhibiting: SKYBRYTE liquid factory glass cleaner. Actual demonstration of SKYBRYTE method of cleaning foundry and machine shop glass.

In attendance: T. T. Holt, president; V. S. Loventhal, treasurer.

**Spencer Turbine Company, Hartford, Conn. Booth 223.**

Exhibiting: 1507 turbo-compressor, 1750 speed, 900 cfm. 1½ lbs. pressure, also one 1010 turbo-compressor, 1300 cfm. 1 lbs. pressure 1750 rpm. and one 1005 machine 600 cu. ft. 1 lb. pressure 3500 rpm.

In attendance: S. E. Philips, secretary; H. M. Grossman, sales engineer.

**Stamets, William K. Company, Pittsburgh. Booths 282 to 292.**

Exhibiting (in operation): Products manufactured by the following:

Hanson-Whitney Machine Company  
Whitney Mfg. Company  
Taylor & Fenn Company  
Lehmann Machine Company  
Morris Machine Tool Company  
Ex-Cell-O Tool & Mfg. Company  
Rockford Machine Tool Company  
Billings and Spencer.  
Neumann's Successors, Friedrich  
Osterlein Machine Company  
Sebastian Lathe Company  
Pels & Co., Henry  
Marschke Mfg. Company  
Kelly Reamer Company

In attendance: W. R. King, W. H. Barber, G. D. Miller, W. E. Tabb and W. K. Stamets.

**Standard Tool Company, Cleveland. Booth 92.**

Exhibiting: Complete line of different styles of twist drills, reamers, taps and milling cutters. Demonstration of different stages through which steel passes in evolution of a drill, a reamer, a tap, and a milling cutter.

In attendance: H. C. McKean, general manager; R. T. Lane, sales manager; E. E. Northway, secretary; H. Will, superintendent; Clarence Buck, metallurgist; T. Bascom, master mechanic; D. R. Higgins, D. G. MacMillan and J. G. Green.

**Starrett Company, L. S., Athol, Mass. Booth 94.**

Exhibiting: Fine mechanical tools; steel tapes; hack saw blades and vises.

In attendance: D. Findlay, sales manager; A. H. Starrett, master mechanic; O. J. Rogers and J. E. Hindes.

**Strong, Carlisle & Hammond Co., Cleveland. Booths 207 to 216 and 224 to 238.**

Exhibiting (in operation): Complete line of machine tools made by following firms:

Monarch Machine Tool Company  
Ames Co., B. C.  
Heim Grinder Company  
Hammond Mfg. Company  
Allen Company, Charles G.  
Knight Machinery Company, W. B.  
International Machine Tool Company

American Tool Works Company  
 Brown & Sharpe Mfg. Company  
 Oilgear Company  
 King Machine Tool Company  
 Bilton Machine Tool Company  
 Oliver Instrument Company  
 Gray Company, G. A.  
 National Automatic Tool Company  
 In attendance: T. W. Carlisle, G. E. Kruger; Detroit and Cleveland representatives; W. H. McClelland, sales manager.

**Strong, Carlisle & Hammond Company, Furnace Department, Cleveland.**  
 Booths 104 and 105.

Exhibiting (in operation): Improved continuous furnace for heating small parts—electrically heated and automatically controlled. High speed and lead hardening furnaces electrically heated. Photographs and descriptions of installations heated by gas or oil.

In attendance: G. S. Peterson, J. Weintz, A. B. Lindsay, T. W. Clark, F. C. Parsons.

**Sun Oil Company, Philadelphia.** Booth 115.

Exhibiting: Samples of machined metal products cut with SUNCO emulsifying cutting oil. Display of petroleum products: cutting oil; motor oil; fuel oil; tempering oil; quenching oils and greases.

In attendance: R. S. Drysdale, chief engineer; C. K. Hague, cutting oil engineer, and C. B. Harding.

**Surface Combustion Company, New York City.** Booth 36.

Exhibiting: Models and designs of furnaces.

In attendance: F. W. Manker, vice president; F. J. Winder, Pittsburgh district manager; C. A. Blesch, engineer Pittsburgh district; A. A. Treadway, Detroit district manager.

**Swedish Crucible Steel Company, Detroit.** Booth 27.

Exhibiting: Nickel alloy and steel castings; carbonizing boxes; lead and cyanide pots; furnace crates; retorts.

In attendance: Henry Nixon, metallurgist; S. R. Allen, sales manager.

**Swindell & Bros., Wm., Pittsburgh.** Booths 28 and 39.

Exhibiting (in operation): Universal electric heat treating furnaces. Photographs.

In attendance: E. H. Swindell, treasurer; R. W. Porter, vice president; F. W. Brooks, chief engineer; G. P. Mills, sales engineer.

**Taylor & Fenn Company, Hartford, Conn.** Booth 283.

Exhibiting: One 2-spindle horizontal spline milling machine. One high speed ball bearing vertical milling machine with circular milling and other attachments. One 3-spindle ball bearing sensitive drilling machine with hand feed, power feed, and tapping head.

In attendance: G. S. DeLany, sales manager; and Niels Carlson, demonstrator.

**Taylor Instrument Companies, Rochester, N. Y.** Booth 112.

Exhibiting: Oil testing thermometers; index thermometers; recording thermometers; thermoelectric pyrometers and new design portable pyrometers.

In attendance: G. A. Howell, H. W. Maurer, Jr.; A. H. Goddard.

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**Thompson Grinder Company, Springfield, Ohio. Booth 259.**

Exhibiting (in operation): 10x36" self-contained universal grinder.

In attendance: H. J. Warriek.

**Thompson & Sons Co., Henry G., Hartford, Conn. Booth 60.**

Exhibiting: Milband positive feed metal cutting machine, and a special exhibit of metal cutting saws.

In attendance: Fellows Thompson, general manager; Graham Thompson, vice president, and T. A. Hyde.

**Timken Roller Bearing Company, Canton, Ohio. Booth 71.**

Exhibiting: Steel sections; tubing; forgings; roller bearings and views of plant.

In attendance: M. T. Lothrop, vice president; A. J. Sanford, steel sales manager; C. A. Swan, assistant steel sales manager; T. W. Hardy, metallurgist; H. W. McQuaid, metallurgist.

**Union Twist Drill Company, Athol, Mass. Booths 272 and 273.**

Exhibiting: Line of milling cutters; hobs; twist drills; reamers; taps; dies; screw plates and similar tools. In operation a grinding machine for sharpening hobs, form cutters, milling cutters and twist drills.

In attendance: J. H. Horrigan, chief engineer; G. F. Holland, general manager, Butterfield & Co. division; L. H. Laythe, sales manager of Butterfield & Co. division; G. E. Stroppe, sales manager of S. W. Card division; G. G. Hunter, Ohio representative of S. W. Card division.

**United Alloy Steel Corporation, Canton, Ohio. Booths 49 and 50.**

Exhibiting: Finished automobiles; locomotive and industrial machinery parts. Various forgings and several rolled axle shafts,—the latter made in our plant. A demonstration of "Enduro" rustless iron.

In attendance: H. H. Pleasance, sales manager; M. H. Schmid, assistant sales manager; F. W. Krebs; R. B. Kelley, Cleveland district manager; J. D. Jones, Detroit district manager; M. A. Grossmann, metallurgical engineer; N. L. Deuble and C. C. Snyder of metallurgical department, and B. H. Shirk.

**Universal Grinding Machine Company, Fitchburg, Mass. Booth 279.**

Exhibiting (in operation): One universal grinding machine, and one cylindrical grinding machine.

In attendance: R. D. Gould, treasurer; G. S. Gould, sales representative.

**Vanadium-Alloys Steel Company, Latrobe, Pa. Booth 64.**

Exhibiting: High speed, alloy and carbon tool steels, tools showing typical and unusual uses of these steels.

In attendance: R. C. McKenna, president; W. S. Jones, vice president; L. D. Moberg, vice president; J. P. Gill and L. D. Bowman, metallurgists; J. H. Roberts, eastern sales manager; W. R. Mau, Chicago sales manager; A. F. McFarland, Detroit sales manager; J. H. Caler, Cleveland sales manager; R. R. Artz, T. J. VandeMotte and G. E. Reminger.

**V & O Press Company, Hudson, N. Y. Booth 254.**

Exhibiting (in operation): No. 41N high speed press equipped with armature disc notching attachment operating at 600 strokes or slides per minute. No. 2 press equipped with double roll feed and scrap cutter. The roll feed will be rack driven, which will insure more accuracy in feeding, also a greater length of feed without gearing.

In attendance: H. U. Herrick, vice president and general manager; F. A. Beardsley, sales manager.

**Walcott Lathe Company, Jackson, Mich.** Booths 264 and 274.

Exhibiting (in operation): Melling crankshaft contour turning lathe. Meling crankshaft pin turning and finishing lathe and a Walcott gear tooth grinder.

In attendance: D. G. Kimball, president and general manager; N. R. Townley, vice president and treasurer; C. H. Sylvester, experimental engineer; R. G. Williams.

**The Warner & Swasey Company, Cleveland.** Booths 262 and 263.

Exhibiting (in operation): One 3-A universal hollow hexagon turret lathe, working on a typical chucking job. A Roto pneumatic grinder demonstrating the possibilities of this new hand tool. One No. 1-A universal hollow hexagon turret lathe.

In attendance: C. J. Stilwell, sales manager; K. L. Pohlman, grinder sales; James Craig, demonstrator; A. C. Cook, vice president, and W. K. Bailey, manager Cleveland territory.

**Westinghouse Electric & Mfg. Co., Pittsburgh.** Booths 96 and 97.

Exhibiting (in operation): Electric furnaces of the latest design. A melting pot will also be exhibited in addition to various interesting details of electric furnace construction.

In attendance: W. S. Scott, manager industrial heating section; R. T. Rutteneutter, M. R. Armstrong, F. G. Allen, H. H. Sugg, all of industrial heating section; J. F. Sweney, Jr., publicity department.

**Wheelock, Lovejoy & Co., Inc., Cambridge, Mass.** Booths 80 and 91.

Exhibiting: HY-TEN alloy steels and WHELCO tool steels, representing processes of manufacture, heat treatment and application to special machine parts.

In attendance: A. O. Fulton, president; F. H. Lovejoy, vice president; E. E. Bartlett, district manager; and G. A. Barch, C. H. Williams and F. F. Blosser of Cleveland; E. P. Gaffney, district manager, and T. W. Knight of New York; L. P. Needham, district manager, and F. J. Devan and A. R. Townsend of Chicago.

**The Whitney Mfg. Company, Hartford, Conn.** Booth 282.

Exhibiting (in operation): Silent chains for power transmission; steel roller chain and sprockets for power transmission.

In attendance: D. I. Wheeler, sales representative; C. E. Wertman, sales manager; S. C. Smith, sales representative.

**Willmarth & Morman Company, Grand Rapids, Mich.** Booth 243.

Exhibiting (in operation): No. 78 surface grinder,—motor drive; No. 3 surface grinder. No. 1 surface grinder. No. 1 universal cutter and tool grinder—motor drive. No. 99 plain universal cutter and tool grinder,—belt drive, less all attachments and countershaft. Type "B" improved NEW YANKEE drill grinder,—motor drive.

In attendance: C. H. Slaughter, sales manager; A. Williams, general superintendent.

**Wilson-Maeulen Company, New York City.** Booth 25.

Exhibiting (in operation): Recording and indicating pyrometer equipment; automatic electrical compensator for pyrometer cold junctions; recording and indicating electric resistance bulb thermometer equipment and accessories; automatic temperature control equipment; Rockwell direct reading hardness tester, including new Model 4-B and new Universal Model D U.

In attendance: J. P. Roberts, Cleveland district representative; C. E. Hellenberg, Detroit district representative; Harvey Lee, Pittsburgh district representative.

## THE REACTIONS AND EFFECTS OF NITROGEN ON STEEL—A SUPPLEMENTARY REVIEW OF LITERATURE

BY C. BALDWIN SAWYER, PH. D.\*

### *Abstract*

*This paper reviews a number of articles dealing with nitrogen in steel.*

*A bibliography of this subject contains about one hundred papers, and the author has selected several of the important ones, abstracting the salient points from each in a comprehensive manner.*

*Sixty references are given in the footnotes.*

*The author of the present paper has done an extensive amount of research work on this subject and numerous of his findings are incorporated in this paper.*

A constantly increasing number of articles on the general subject of nitrogen in steel reflect its importance. A bibliography of the literature contains in the neighborhood of a hundred references, and a large majority of the authors who are concerned with mechanical properties find that nitrogen in small quantities can cause a great loss of ductility.

In the issue of March 3, 1920, page 399, of *Chemical and Metallurgical Engineering*, Messrs. Comstock and Ruder present an excellent review of the literature. The main part of the present article supplements their work by adding more references and abstracts in chronological order. At the end appears a resumé of the opinions of the various authors on some of the most important phases of the subject.

Iron may react with nitrogen in a number of ways. In 1881, Remsen<sup>1</sup> stated that "when iron by hydrogen and certain non-nitrogenous organic substances (such as the sodium tartrates) are heated together with metallic sodium in an atmosphere of nitrogen, a cyanide is readily formed." This statement suggests the Bucher<sup>2</sup> process of today, in which iron catalyses at red heat the formation of cyanide from nitrogen, carbon and alkalies.

Howe<sup>3</sup> states that iron unites with nitrogen when the gas is

<sup>1</sup>*Journal, American Chemical Society, Vol. 4, 1881, page 134.*

<sup>2</sup>The Brush Laboratories Co., Cleveland.

passed over iron oxide while it is being reduced with hydrogen. This, we now know, it probably due to the formation of small quantities of ammonia which combine with the iron. It may account for the brittleness sometimes observed after hydrogen annealing. Howe<sup>4</sup> later notes that from fresh fractures of ingots and other castings, and sometimes even from rails, a strong smell of ammonia sometimes escapes, which unquestionably proceeds from the metal itself. This observation indicates that nitrogen may react with molten iron, as has been proved by Andrew<sup>5</sup>.

Baur and Voerman<sup>6</sup> after nitrifying iron wire by heating in ammonia, attempted to measure the dissociation pressure of iron nitride at various temperatures. They also electrically heated bright iron wire in an atmosphere of nitrogen, to a temperature just below the melting point, but produced no noticeable absorption of the nitrogen, as tested by gain in weight. They concluded that the dissociation pressure of iron nitride is in excess of 14 atmospheres.

Le Chatelier, in the discussion of Braune's<sup>7</sup> paper, pointed out that acid and basic steels of the same composition and heat treatment do not have the same mechanical properties. Osmond<sup>8</sup> had often noticed the presence of Neumann lines in brittle metal, similar to Braune's. Le Chatelier thought, therefore, that the presence of Neumann lines might have a connection with the nitrogen content of the steel.

Le Carme<sup>9</sup> carried out a series of experiments on the bending of cemented low-carbon iron bars. Though his methods are not above criticism, his results cannot be ignored. His work may be summarized as follows: A chemical transformation without an increase in carbon seems to take place in the heart of low-carbon iron bars when these are cemented in wood charcoal. This transformation is of a nature such that quenching from 800 degrees Cent. renders

<sup>3</sup>Journal, Industrial and Engineering Chemistry, Vol. 9, 1917, page 233.

<sup>4</sup>Howe, "The Metallurgy of Steel," page 106.

<sup>5</sup>Ibid, page 110.

<sup>6</sup>Journal, Iron and Steel Institute, No. 2, 1912, 210.

<sup>7</sup>Zeitung für Phys. Chemie, Vol. 52, 1905, page 466.

<sup>8</sup>Revue de Metallurgie, 1905, page 497.

<sup>9</sup>Revue de Metallurgie, No. 1, 1904, page 11.

<sup>10</sup>Revue de Metallurgie, No. 2, 1905, page 516.

the heart brittle and martensitic. The effect is not found when pure graphite replaces wood charcoal.

Wood charcoal, of course, contains alkali bases which, in the presence of carbon, nitrogen and iron, might react with the formation of cyanides, according to the Remsen<sup>10</sup> reaction. Le Chatelier, in discussing Le Carme's paper, states that Braune's<sup>11</sup> work on the harmful effect of nitrogen, lends a certain probability to Le Carme's results.

In 1907, Braune<sup>12</sup> published a separate article on the cementation of steels. Using two cements, he found by analysis that bone charcoal introduced more nitrogen into the cemented iron bars than did birch charcoal. The fragility increased with the nitrogen concentration, which, in turn, varied with the quantity of cyanide, or with the quantity of sodium and potassium salts present in the cement. Thus, irons cemented in washed graphite at a very high temperature showed no increase in nitrogen content and were very tough, even with an outer case containing 0.70 per cent of carbon.

Working with the three cements, pure wood charcoal, burnt leather and barium carbonate mixed with wood charcoal, Scott<sup>13</sup> found at 900 degrees Cent. a velocity of penetration greatest for the barium carbonate mixture and increasing in the order named. Other experiments lead the reader to conclude that the presence of nitrogen compounds, or of substances capable of forming nitrogen compounds, increases the velocity of penetration, and diminishes the temperature necessary for cementation. Thus Scott finds little penetration with hard coke or anthracite.

Kirner<sup>14</sup> has made an extremely interesting contribution. Working with three cements capable of introducing nitrogen, he confirms previous findings and contributes new information, as follows:

1. Higher temperatures increase carbon in cemented zones, but,
2. Decrease nitrogen contents.

<sup>10</sup>Loc. Cit.

<sup>11</sup>Loc. Cit.

<sup>12</sup>*Stahl und Eisen*, Vol. 27, 1907, page 1395.

<sup>13</sup>*Journal*, Iron and Steel Institute, Vol. III, 1907, page 120

<sup>14</sup>*Revue de Metallurgie*, No. 8, 1911, page 72

3. Leather charcoal introduces more nitrogen than wood charcoal.
4. A peculiar cement, containing besides carbon, 41 per cent of sodium chloride, 9 per cent of nitrogen and 18 per cent of  $\text{Fe}_2\text{O}_3$ ,  $\text{Al}_2\text{O}_3$  and  $\text{CaO}$ , gave a very energetic cementation at only 700 degrees Cent. resulting in a case containing about 0.50 per cent of carbon and 0.56 per cent nitrogen.
5. At 900 degrees Cent. this cement produced a case containing about 0.50 per cent carbon and only 0.03 per cent nitrogen.
6. In zones containing considerable nitrogen a special metallographic constituent was observed.

Kirner's observations concerning the important effects of sodium chloride are reinforced by the fact that mixtures containing it are listed elsewhere<sup>15</sup>.

Hanemann,<sup>16</sup> in a dissertation presented at Berlin, studied the rate of rusting of iron containing nitrogen. Nitrifying solid iron samples in ammonia at temperatures greater than 600 degrees Cent., he formed an outside layer of  $\text{Fe}_2\text{N}$  or a solid solution of  $\text{Fe}_2\text{N}$  in  $\text{Fe}_3\text{N}$ , which overlayed a fine mixture of iron and iron nitride. The outside layer resisted corrosion and had noble metal characteristics as confirmed by an electrode potential of  $E_h = -0.512$  volts. If, however, the outside protective layer was broken, a galvanic couple capable of generating a potential of 0.9 volts in normal iron sulphate solution, was formed in the fine material beneath and greatly accelerated corrosion.

In Dresden, during the same year, Wolfram<sup>17</sup> presented a dissertation. He was concerned with the combination of pure and commercial iron with gaseous nitrogen. Iron reduced by hydrogen, when heated in an atmosphere of nitrogen, appeared to absorb 0.25 per cent nitrogen at 500 degrees Cent., and 0.80 per cent at 980 degrees Cent. Part of this may have been due to "occlusion." By heating various iron alloys nearly to their melting point in an atmosphere of nitrogen, Wolfram determined that after the treatment they contained nitrogen by analysis as follows: Pure iron 0.022 per cent; spiegeleisen 0.059 per cent; ferro-manganese 0.46 per cent;

<sup>15</sup>Giolitti, "Cementation of Iron and Steel," page 262.

<sup>16</sup>Königl. Technischen Hochschule, 1913.

<sup>17</sup>Königl. Sachsischen Technischen Hochschule, 1913.

iron carbide 0.045 per cent; ferro-nickel 0.055 per cent; pure manganese 5.2 per cent.

Herwig<sup>18</sup> has contributed valuable information. He was interested in blisters which formed during the annealing of sheet iron. These contained 90 per cent of nitrogen, even when the annealing was performed in carbon dioxide. To track down the effect of nitrogen, he had sheets rolled and annealed from two ingots, one made as usual and the other nitrified by adding lumps of calcium nitride during the pouring. Sheets rolled from the nitrified ingot varied from 0.018-0.038 in per cent of nitrogen, but all of them were covered with blisters, while those from the un-nitrified ingot were smooth. A second pouring checked the results of the first. A rail containing 0.04 per cent nitrogen showed little elongation, although the phosphorous content had been much reduced by the addition of calcium nitride.

Experimenting with steel shavings heated to a temperature just below the melting point in an atmosphere of pure nitrogen, Herwig could detect no absorption. But with hydrogen mixed with the nitrogen, the steel shavings rose in nitrogen content to 0.032 per cent. Pure hydrogen, passed over nitrified shavings, reduced the nitrogen content to 0.006 per cent and ammonia was present in the escaping gas.

Many analyses of Thomas iron showed that it contains 0.014 per cent of nitrogen, an amount greater than found in the pig iron from which it was made. Herwig concluded that moisture in the air blown into the Thomas furnace is responsible, because of its hydrogen, for the increased nitrogen content.

Moldenhaur<sup>19</sup> passed pure nitrogen over finely divided iron reduced from the oxide. Up to 600 degrees Cent. about 0.25 per cent of nitrogen was absorbed independently of the temperature. However, as the temperature increased above 600 degrees Cent., the nitrogen absorbed became less, until at 850 degrees Cent. it had fallen to a value of 0.05 per cent.

Jurisch<sup>20</sup> supplementing and confirming the work of Moldenhaur, investigated the absorption of nitrogen by finely divided steel heated to about 900 degrees Cent. in an atmosphere of the gas. The quantity absorbed was 0.022 per cent at atmospheric pressure and

<sup>18</sup>*Stahl und Eisen*, Vol. 33, 1913, page 1721.

<sup>19</sup>*Zeitung für Angew. Chemie*, Vol. 27, 1914, page 329.

<sup>20</sup>*Stahl und Eisen*, Vol. 34, 1914, page 252.

875 degrees Cent., but varied with the square root of the pressure and decreased slightly with increase of temperature.

In an important investigation described by Baraduc-Muller<sup>21</sup>, a large amount of liquid basic Bessemer steel was poured after deoxidation with ferro-manganese, into an air tight crucible and subjected to the action of a vacuum. Gases obtained by the pumps during solidification and cooling of the steel were collected, measured and analyzed. In spite of the deoxidation by ferro-manganese sufficient nitrogen was recovered to correspond to about 0.03 per cent in the steel as poured into the ladle.

Dudley<sup>22</sup> found that steel rails containing 0.0147 to 0.0153 per cent of nitrogen were likely to break in service. Ferro-titanium raises the ductility of acid Bessemer rails.

Hurum<sup>23</sup>, besides greatly improving the method of nitrogen determination<sup>24</sup>, made exact measurements of carbon and nitrogen penetration during case hardening and thus constructed many concentration-depth diagrams. Nitrogen, in general, penetrates farther than carbon, and has a definite maximum concentration as the temperature of cementation is varied. Cyanides and cyanamides introduce much more nitrogen than bone charcoal. (Fay<sup>25</sup>).

Working with a pressure furnace capable of handling ammonia up to 80 pounds per square inch, Hurum nitrified iron wires  $\frac{1}{8}$  inch in diameter and demonstrated that with proper heat treatment, steel containing 0.10 per cent of nitrogen could have a tensile strength of 137,000 pounds per square inch and an elongation of 8 per cent in 2 inches.

Hurum also treated iron wires of  $\frac{1}{8}$  inch diameter in molecular nitrogen at 120-150 pounds pressure and found that at 850 degrees Cent. 0.078 per cent of nitrogen was absorbed.

Rawdon, Groesbeck and Jordan<sup>26</sup> are concerned with the arc welding of steel. In confirmation of the results of other authors (see Comstock and Ruder) weld metal was found to contain about 0.130 per cent of nitrogen and was not ductile. The lack of ductility is, however, attributed by the authors to general unsound-

<sup>21</sup>Carnegie Scholarships Memoirs, 1914, page 216.

<sup>22</sup>Journal, Industrial and Engineering Chemistry, 1914, page 299.

<sup>23</sup>Doctorate Thesis, Massachusetts Institute of Technology, 1919.

<sup>24</sup>Chemical and Metallurgical Engineering, Vol. 26, 1922, page 218.

<sup>25</sup>Chemical and Metallurgical Engineering, Vol. 24, 1921, page 289.

<sup>26</sup>Chemical and Metallurgical Engineering, Vol. 23, 1920, page 677 and page 777.

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ness of the metal. In support of this view they have found many slip planes developed upon plastic deformation of the weld metal. This is thought to indicate an inherent ductility, which is masked by the unsoundness.

Quenching weld metal from 950 degrees Cent. causes the nitrogen needles to vanish, but these reappear on reheating. Heating in a vacuum for 6 hours at 1000 degrees Cent. decreases the nitrogen content to 0.006 per cent, but at the same time increases the prominence of nitrogen needles. This inconsistency, they think, may be due to conversion by heating of other forms of nitrogen into nitride nitrogen, the only form determined by the distillation method.

Wheeler<sup>27</sup> has added to the evidence that nitrogen may exist in steel in a form not determined by ordinary methods. The inside of containers, used at elevated temperatures in the Haber process for making ammonia, developed a light structureless zone likely to cause failure. Cold working greatly increased the hardness of this zone. However, no analyses for nitrogen were made and the evidence is not complete.

Knight and Northrup<sup>28</sup> passed ammonia over steel at 650 degrees Cent. The outside layer of steel thus heavily nitrified, was resistant to corrosion, except where cracked. This confirms the previously cited observations of Hanemann concerning corrosion.

The total number of layers observed by Knight and Northrup in low-carbon steel were five. Weight is given to this observation by the work of Noyes and Smith<sup>29</sup> whose studies of the equilibrium between iron and unstable ammonia indicate the existence of the four nitrogen compounds,  $\text{Fe}_8\text{N}$ ,  $\text{Fe}_6\text{N}$ ,  $\text{Fe}_4\text{N}$ ,  $\text{Fe}_2\text{N}$ , and still later by the magnetic researchers of Kido<sup>30</sup>, who found in nitrified steel four distinct compounds with definite transformation points.

In work completed at the Massachusetts Institute of Technology in 1921, Sawyer<sup>31</sup> obtains results as follows:

1. All nitrogen introduced into carbon steel by ammonia or by case-hardening processes is determined by the distillation method.

<sup>27</sup>*Mining and Metallurgy*, Vol. 160, 1920.

<sup>28</sup>*Chemical and Metallurgical Engineering*, Vol. 23, 1920, page 1107.

<sup>29</sup>*Journal*, American Chemical Society, Vol. 43, 1921, page 475.

<sup>30</sup>*Chemical Abstracts*, Vol. 16, 1922, page 2296.

<sup>31</sup>*Transactions*, American Institute of Mining and Metallurgical Engineering, Vol. 59, 1923, page 798.

2. A combustion method for determining the total nitrogen content of steel thus far gives results in agreement with the distillation method, independently of the way in which the steel was nitrified.

3. Iron melted under an atmosphere of nitrogen absorbs it in accord with the formula:

$$\% N = k\sqrt{P_n}$$

where % N = per cent of nitrogen in cooled ingot;  $k$  = a constant having value of 0.020 for pure iron

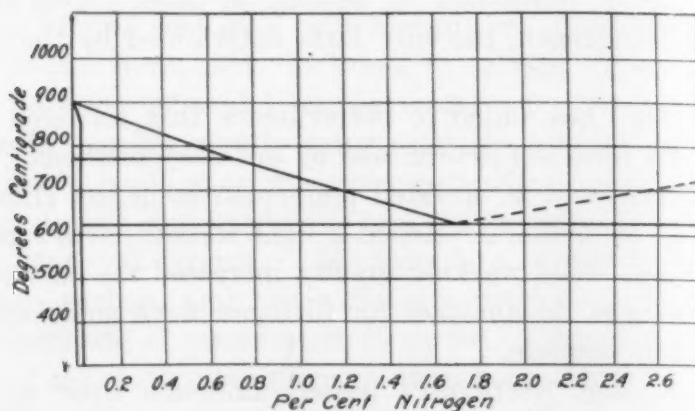


Fig. 1—Iron-Nitrogen equilibrium diagram according to Sawyer.

$P$  = pressure in atmosphere, of nitrogen during melting and solidification.

4. Nitrogen can exist in ferrite in solid solution up to approximately 0.03 per cent.

5. The amount of nitrogen remaining in nitrified steel after reheating is dependent on the reheating temperature, decreasing as it is raised.

6. The iron-carbon and iron-nitrogen (Fig. 1) equilibrium diagrams are similar, but in the latter the eutectoid composition is at 1.70 per cent of nitrogen, with a transformation point on heating at 620 degrees Cent.

7. In non-uniformly nitrified steel containing 3 to 4 per cent nitrogen, the existence of a second eutectoid is indicated by a second transformer point at 693 degrees Cent. and by microscopical examination. The two eutectoids postulate two nitrogen compounds, in addition to iron. Microscopical analysis reveals a third compound, agreeing with Knight and Northrup, Noyes and Smith, and Kido.

8. Those bending tests which could be performed on the small samples available, indicated a great loss of ductility for steel containing more than 0.015 — 0.030 per cent of nitrogen.

Brophy and Leiter<sup>32</sup> and Ruder and Brophy<sup>33</sup> are concerned with the metallographic action of Stead's reagent in case-hardened steels of various compositions. They show many photomicrographs indicating the presence of nitrogen in the case. This is in agreement with the conclusions of preceding investigators, that nitrogen plays an important role in commercial case hardening.

Wust and Duhr<sup>34</sup> using a modified distillation method for determining nitrogen have found that chromium, manganese, ferro-titanium, ferro-aluminum and ferro-vanadium have a great affinity for nitrogen, thus confirming the previous observations of Tschischewski<sup>35</sup>. On the other hand, ferro-chromium and ferro-manganese absorb only small amounts of nitrogen, and ferro-phosphorus and ferro-tungsten none at all.

In addition, they make an interesting statement that electrolytic iron in powder form can absorb 0.227 per cent of nitrogen in twelve hours at 960 degrees Cent. when heated in a stream of the gas.

Analyses by Wust and Duhr of iron made by the puddling, and by the Siemens-Martin processes show nitrogen contents less than 0.008 per cent, while in the (Thomas) basic Bessemer process the nitrogen content may vary from 0.006 to 0.026 per cent.

Jordan and Swindells<sup>36</sup>, examining the distillation method for determining nitrogen in steel, made important recommendations for modifying the Allen method, and place great reliance on the accuracy of their procedure. In the course of their analyses of certain commercial steels of comparatively low nitrogen content (about 0.01 per cent) they find that a normalizing quench from about 1000 degrees Cent., can increase the nitrogen content of some, but not all, of these steels. They, therefore, conclude that nitrogen may exist in the steel in two forms, one of which is more or less converted into nitride-nitrogen by the quenching treatment and therefore becomes capable of determination by the distillation method.

<sup>32</sup>TRANSACTIONS of American Society for Steel Treating, No. 6, 1921.

<sup>33</sup>Chemical and Metallurgical Engineering, Vol. 25, 1921, page 867.

<sup>34</sup>Mitt. Kaiser Wilhelm Institut Eisenforsch, Düsseldorf, Vol. 2, 1921, page 39-57.

<sup>35</sup>Journal, Iron and Steel Institute, Vol. 92, Part II, 1915, page 47.

<sup>36</sup>Scientific Paper, Bureau of Standards, No. 357, 1922.

In a second article evidently supplementing the work by Wust and Duhr, Wust<sup>37</sup> examines the nitrogen content of steel prepared by the Thomas method (basic Bessemer), at ten different works. At each works four analyses were made as follows: (1) of the cast iron poured into converter; (2) of the steel before deoxidation; (3) of the steel after deoxidation; and (4) of the steel remaining in the ladle after pouring the last ingot. Ferro-manganese varying in manganese content was employed, and added in both solid and liquid form, but results show no significant lowering of nitrogen content by deoxidizing. Average nitrogen contents following deoxidation were 0.015 per cent but occasionally they rose to 0.024 per cent. The original cast iron poured into the converter contained only about a tenth of this amount and Wust concludes that the nitrogen in Thomas steel is absorbed mainly during blowing. He confirms this by further determinations of nitrogen content at various stages of the blowing and gives results in curves showing the variation in content of nitrogen, carbon, manganese, and silicon as the blowing proceeds. Wust notices a sudden increase in the rate of absorption of nitrogen simultaneous with the beginning of the after-blow and phosphorus elimination. However, it is apparent from his curves that this moment corresponds also to the practically complete elimination of carbon from the steel, and therefore, to the end of the formation of carbon monoxide, the presence of which lowers the partial pressure of nitrogen in the blast.

Wust concludes that the chief factors affecting the nitrogen content of basic Bessemer steel are the temperature of the steel during the blow and the pressure of the blast. An increase in either tends to increase the nitrogen content.

In an endeavor to develop a new method for case hardening, which should be free from the troubles of distortion, Fry<sup>38</sup> incidentally carried out a research on the equilibrium diagram of iron and nitrogen. Believing that the difficulties of thermal analysis made that method unsuited to his research, Fry adopted other less precise methods. Data obtained by these methods are incorporated in the accompanying diagram copied from Fry's published article (Fig. 2). His diagram agrees in a satisfactory way with that of Sawyer's (Fig. 1).

In obtaining the eutectoid concentration of 1.5 per cent nitro-

<sup>37</sup>Mitt. Kaiser Wilhelm Institut Eisenforsch., Düsseldorf, Vol. 4, 1922, page 95.

<sup>38</sup>Kruppsche Monatshefte, Vol. 4, 1923, page 137.

gen and the temperature of 580 degrees Cent. for eutectoid transformation, Fry worked with steel containing about 0.13 per cent carbon. This fact probably accounts for the difference between his values and the corresponding ones of 1.70 per cent nitrogen and 620 degrees Cent. for eutectoid composition and temperature obtained by Sawyer with carbonless iron.

Concerning the magnetic inversion at 480 degrees Cent. disclosed in Fry's equilibrium diagram, it is not supposed that steels

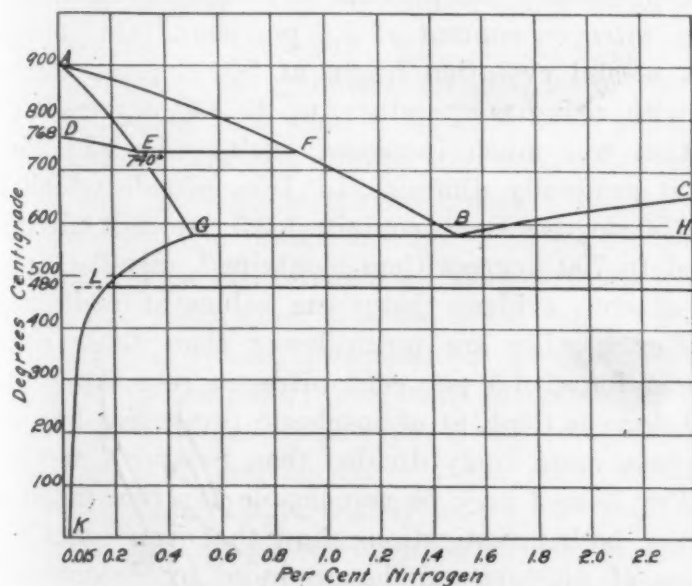


Fig. 2—Iron-Nitrogen equilibrium diagram according to Fry.

of medium or low nitrogen content—from 0 to 1.5 per cent nitrogen—undergo any great loss of permeability at this temperature. What magnetic effect exists is obscured by the comparatively large amount of magnetic alpha iron present in such material, and is not at all comparable with the loss of magnetism in ordinary steels at their "hardening temperatures." This nitrogen magnetic inversion at 480 degrees Cent. should be of value chiefly in investigating iron of high nitrogen content.

On the other hand the information given by Fry concerning the increase in solubility of iron nitride in alpha iron with increase in temperature is of great practical importance. According to him, nitrogen may exist in solid solution in annealed low carbon iron at room temperature only to the extent of 0.015 per cent; but at 500 degrees Cent. the solubility is increased to 0.2

per cent; and at 550 degrees Cent. it rises to about 0.4 per cent. This increase in solubility may be of the greatest importance in heat treating nitrified steels. It reminds one of a similar increase in solubility of  $\text{CuAl}_2$ , made use of in the heat treatment of aluminium alloys. Investigation of iron-nitrogen alloys in this region should be fruitful.

Fry also heated  $\text{Fe}_2\text{N}$  in a vacuum to various temperatures. He found an evolution of nitrogen beginning at 440 degrees Cent. and practically complete at 550 degrees Cent. with a corresponding nitrogen content of 5.6 per cent. On continuing the heating, a second evolution began at 560 degrees Cent. and diminished with rising temperature, up to 630 degrees Cent., when the evolution was much increased again. At still higher temperatures it gradually diminished. Iron nitride which had been heated to 650 degrees Cent. contained 0.5 per cent nitrogen, while that heated to 700 degrees Cent. contained only 0.11 per cent.

It is at once evident that these values of residual nitrogen content after heating are much lower than those obtained by Sawyer, who found 1.5 per cent nitrogen remaining after heating to 800 degrees Cent. at atmospheric pressure. Fry's material may have been more finely divided than Sawyer's or the vacuum in which Fry heated may be responsible for the different result. At all events, both investigations show that iron containing varying amounts of nitrogen can be produced by decomposing nitrified iron with heat, though such factors as the pressure of surrounding atmosphere and thickness of material have important effects on the results obtained.

The iron nitride used by Fry in these decomposition experiments contained no carbon, and it is interesting to note the close correspondence of the temperature of 630 degrees Cent., at which his third evolution of nitrogen occurred, with the temperature of 620 degrees Cent. given by Sawyer for the eutectoid change. As explained above, the eutectoid temperature of 580 degrees Cent. as determined by Fry is probably lower because of the presence of carbon.

With reference to the thermal effect observed by Sawyer at 620 degrees Cent., and ascribed by him to an eutectoid change, it is stated in Fry's article that on the basis of work therein described one can confidently conclude that this thermal effect of Sawyer's does not mean an  $\text{Ac}_1$  change but, rather, a decomposi-

tion effect. In answer to this statement, it suffices to point out that all of Sawyer's samples, in which this effect at 620 degrees Cent. was observed, had been heated previously to much higher temperatures, ranging, as a matter of fact, between 800 degrees Cent. and 1000 degrees Cent. All decomposition effects of the kind cited by Fry must have been completed at these higher temperatures, and, therefore, could not account for the  $A_{c_1}$  effect observed by Sawyer. Further, since the results of the two investigations agree so closely, it is difficult to doubt those of one without doubting those of the other.

Working with iron cylinders nitrified in a stream of ammonia, Fry confirms in a general way the observations of others as to the several layers of different structure which are thus produced. In one of these layers he observes twins, as has been noted by Sawyer. He finds the same twins in nitride needles.

Certain alloy steels nitrified at temperatures less than 580 degrees Cent. showed a great increase in hardness, without quenching and, therefore, without deformation. One such steel contained 0.50 per cent carbon, 2.30 per cent chromium, 1.75 per cent aluminium. In another similar steel, the composition of which is not given, the Brinell hardness of the case exceeded 750 and could not be determined accurately as the ball flattened.

Parravano and Scortecchi have published, in Italian, results comparing the combined nitrogen content of various steels and alloys with the nitrogen extracted by heating them in a vacuum. Only the abstracts<sup>39, 40</sup> of this work are available to the writer. It appears that at least part of the nitrogen extracted by heating steel in a vacuum is due to the decomposition of nitrides, as has been found by other authors.

Working with iron alloys constituted in large part by one or more of the elements: manganese, chromium, vanadium, titanium, silicon or calcium, Parravano and Scortecchi investigated the effect of fusion upon the amounts of nitrogen extracted by heating in a vacuum and determined as nitrides. They conclude that, in accord with Jordan and Swindells, part of the gaseous nitrogen is transformed into combined nitrogen during fusion. From the study of these abstracts, it does not seem to the writer that sufficient attention has been paid to the possibility of ex-

<sup>39</sup>*Chemical Abstracts*, Vol. 18, 1924, page 3030.

<sup>40</sup>*Chemical Abstracts*, Vol. 19, 1925, page 1122.

change of nitrogen in either direction between the alloy and the atmosphere during melting.

In two articles also in Italian, Musatti and Croce present results of an investigation into the rôle of nitrogen in the process of cementation. As before, only abstracts of this work<sup>41, 42</sup> are available to the author. Working with solid commercial cements capable of introducing relatively small amounts of nitrogen, Musatti and Croce conclude that nitrogen has a catalytic action in cementation. In accord with Hurum, it diffuses faster into the steel than carbon and tends to accelerate the whole process of cementation. The amounts of nitrogen introduced depend on the temperature and decrease above an optimum, as has also been noted by other authors.

Concerning the effect of nitrogen on the mechanical properties, Musatti and Croce conclude that very low resiliences are characteristic of a needle structure which is formed when cooling takes place at a rate slower than during normalizing. When the needle structure is altered so as to become pearlitic, the resilience becomes high.

J. Kent Smith<sup>43</sup> states that the determination of nitrogen in steel is complicated, owing to the many different nitrides possible, some of which may not be determined. He finds that steels low in nitrogen roll easily, in agreement with Braune, who found that normal steel containing nitrogen is extremely unforgeable. Smith states that free molecular nitrogen obviously does not enter directly into combination with iron as otherwise iron and steel by present day processes would be full of it. He concludes that nitrogen must be introduced in the blast furnace by cyanides, evidently overlooking the work by Andrew, Sawyer and Wust. Titanium and vanadium mitigate the harmful effects of nitrogen.

Tchijevski<sup>44</sup> is concerned with the determination of nitrogen in steel. He confirms the conclusions of other investigators that in the distillation process alkalis can be derived from glass condensers; that a dephlegmator is advisable; and that corks must be protected by tin foil.

Oberhoffer and Heger<sup>45</sup> studied the equalization of segrega-

<sup>41</sup>*Chemical Abstracts*, Vol. 18, 1924, page 3031.

<sup>42</sup>*Chemical Abstracts*, Vol. 19, 1925, page 1680.

<sup>43</sup>*Iron Age*, 1924, page 1209.

<sup>44</sup>*Revue de Metallurgie Extraits*, Vol. 21, 1924, page 414.

<sup>45</sup>*Stahl und Eisen*, Vol. 43, 1923, page 1474.

tions in steel by heating specimens 10 millimeters thick to temperatures between 1100 and 1300 degrees Cent. in an atmosphere of nitrogen. Incidental to the results sought by them, they found in accord with Hurum that nitrogen is absorbed by the steel under these conditions. At the end of 40 hours, the nitrogen content of the cross-section was 0.019 per cent and slowly rose to 0.020 per cent at the end of 200 hours.

Willey,<sup>46</sup> with reference to arc welding, studied the products deposited on the walls of a glass container when an arc was struck between electrodes of iron in an atmosphere containing nitrogen. He concludes that besides iron containing about 0.2 per cent of nitrogen, a second nitrogeneous substance is formed when some oxygen is present with the nitrogen.

Klinger<sup>47</sup> studied the composition of gas given off by basic Bessemer steel from the time of pouring into the mould until solidification is complete. He concludes that carbon monoxide preponderates in gas evolved from material not well deoxidized, while hydrogen preponderates from "killed" steel. Unfortunately, Klinger was not able to measure accurately the amounts of gas given off during cooling by deoxidized and not-deoxidized steel. Nevertheless, he concludes that the amounts of gas given off by a killed charge were significantly smaller than those from one which had not been killed. Also, the addition of ferro-silicon reduced the evolution of gas to such an extent that samples for analysis could be taken only during the period of solidification. Respecting the amounts of gas given off during solidification, no difference was observed between steel which had been killed and that which had not. This leaves the reader to conclude that in basic Bessemer steel, the present deoxidizers always leave sufficient gases dissolved in the steel to cause evolution during the concentration accompanying solidification.

The work of Klinger is the last to appear at the time of this writing. Following is a summary of the opinions of various writers on some important phases of the subject.

That free nitrogen can be absorbed by molten steel is established by the results of Andrew, Sawyer and Wust. That it is also absorbed by solid iron at red heat follows from the statements of Wolfram, Moldenhaur, Jurisch, Hurum, Wust and Duhr, and

<sup>46</sup>*Journal, Society of Chemical Engineering*, Vol. 43, 1924, page 263.

<sup>47</sup>*Krupp. Monatsh.*, Vol. 6, 1925, page 11.

Oberhoffer and Hager. At temperatures just below the melting point, and at atmospheric pressures, Wolfram found 0.022 per cent absorbed by pure iron, while according to Sawyer, 0.021 per cent remains in iron cooled from just above the melting point. These amounts are in substantial agreement with Strauss' figure of 0.020 per cent for acetylene welds. Jurisch, Baraduc-Muller, Wust, and Oberhoffer and Hager tend also to confirm this figure. These limiting amounts, both for solid and liquid iron, probably increase when any of the elements silicon, manganese, aluminium, titanium, or vanadium are present in the iron (Tschischewski, Wust and Duhr), or when the temperature of treatment is lowered (Moldenhaur, Jurisch, Hurum, Wust and Duhr).

Herwig, on the other hand, could not detect absorption of free nitrogen by steel shavings, even when heated to a temperature just below the melting point, unless some hydrogen were present. Possibly, traces of hydrogen must always be present for absorption to proceed. Hydrogen probably acts as a catalytic carrier by forming ammonia, as in the Haber process. Both nitrification and denitrification have been noticed in its presence. (Howe, Allen,<sup>48</sup> Herwig, Strauss, Noyes and Smith, Ruder and Sawyer.)

Many authors have proved the presence of nitrogen in arc welds up to about 0.15 per cent. The ionizing action of the arc is probably responsible for the high content. In this case it cannot be said that nitrogen gas combines directly with molten iron.

Ammonia and cyanides are universally conceded to be nitrifying agents. Shimer<sup>49</sup> has shown that cyanamides have the same power, as is probably also the case with amines. Lately Benson<sup>50</sup> has found nitrogen in steel annealed in sodium nitrate baths.

That most commercial case-carburizers introduce nitrogen as well as carbon into steel is abundantly shown by the works of Remsen, Le Carme, Braune, Scott, Kirner, Hurum, Bucher, Fay, Brophy and Leiter, Ruder and Brophy, and Musatti and Croce. As first pointed out by Fay<sup>51</sup>: "This reaction is undoubtedly a general one, whenever iron, carbon, alkali, and air, or nitrogen, are heated together. There is a formation of cyanide, and the

<sup>48</sup>*Journal, Iron and Steel Institute, 1880, page 181.*

<sup>49</sup>*TRANSACTIONS of American Society for Steel Treating, Vol. 2, 1922, page 403.*

<sup>50</sup>*Journal, Iron and Steel Institute, Vol. 106, 1922, page 95.*

<sup>51</sup>*Chemical and Metallurgical Engineering, Vol. 24, 1921, page 290.*

cyanide in turn reacts with iron, forming nitride and carbide."

With nitrogen capable of entering into combination with iron in so many ways, much has been written and deserves to be written concerning its effects on the mechanical properties. That it can and does make iron very brittle is universally conceded. Just how much is required to accomplish this is uncertain, but the maximum and minimum limits of this critical amount are approaching each other. Thus the following authors have found that nitrogen in amounts varying between 0.02-0.06 per cent can produce great loss of ductility:

Osmond, Tholander, Braune,<sup>52</sup> Giesen,<sup>53</sup> Herwig, Stromeyer,<sup>54</sup> Dudley, Tschischewski, Strauss, Ruder and Sawyer.

Amounts of nitrogen as great as these are not unknown in commercial steels, and the effect should, therefore, be carefully investigated, even though Harbord.<sup>55</sup> Saniter,<sup>56</sup> and Pourcel<sup>57</sup> do not consider amounts in commercial steel great enough to warrant concern. Arc welds, however, always contain more than the above maximum limit of nitrogen and are brittle. Miller,<sup>58</sup> and Rawdon, Groesbeck and Jordan indicate that this brittleness is due to oxide inclusions or films, and not to nitrogen, but the point is not proved.

By properly heat treating steel containing 0.10 per cent of nitrogen, Hurum has produced material of good quality. Moreover, the writer is informed, the Rail Welding and Bonding Company of Cleveland have recently developed a process of heat treatment for arc welded joints which consists, essentially, in reheating the weld metal by a modified treatment with the arc. The resulting joint is said to be much refined in grain and superior in ductility. The heat treatment of nitrified steel, therefore, appears to be very important, and should be worked out coincidentally with the effect of nitrogen on commercial hot rolled steel.

In heat treating nitrified steels one should not overlook the tendency of nitrogen to escape from them at elevated temperatures. This tendency is implied in the works of Baur and Voer-

<sup>52</sup>*Stahl und Eisen*, 1889, page 115.

<sup>53</sup>Carnegie Scholarship Memoirs, 1909, page 1.

<sup>54</sup>*Journal*, Iron and Steel Institute, 1901, No. I, page 404.

<sup>55</sup>*Journal*, Iron and Steel Institute, 1896, No. II, page 161.

<sup>56</sup>Discussion of Stromeyer's paper.

<sup>57</sup>*Revue Universelle des Mines*, Vol. 15, page 229.

<sup>58</sup>*Transactions*, American Institute of Mining Engineers, Vol. 78, 1918, page 700.

man, Kirner, Herwig, Moldenhaur, Strauss, Noyes and Smith, Hurum, and quantitatively indicated by Sawyer and Fry. Certainly the outer surface of highly nitrified steel may easily become denitrified on heating.

In more recent literature there has been a tendency to account for discrepancies observed in working with nitrified steels, by assuming the existence of a second form of nitrogen in steel which is different from "nitride nitrogen" and not determined by the distillation method. This assumption has never been proved, and determinations following different heat treatments may not agree due either to accompanying absorption or evolution of nitrogen, or to the formation of different nitrides. Although present information does not warrant a general conclusion concerning the existence or otherwise of this second form of nitrogen, nevertheless, in the special cases of low carbon-steel or iron nitrified by ammonia or cyanides, the gain-in-weight experiments of Fowler,<sup>59</sup> Beilby and Henderson,<sup>60</sup> Tschischewski, Hurum, and Sawyer indicate that no nitrogen escapes determination by the distillation method.

From a study of the work done on nitrogen in steel, it is evident that information is most needed about the mechanical properties. The writer melted about a kilogram of Armeo iron in an atmosphere of nitrogen at a pressure of 80 pounds per square inch, but was unable to forge the resulting ingot into test bars, owing to its extreme brittleness at red heat. That this brittleness was due to nitrogen (about 0.035 per cent) is not established, but the result is in agreement with the observations of Braune and J. Kent Smith. Perhaps a better way to produce samples of nitrified steel in a form suitable for testing would be to heat wire of about an eighth inch in diameter to 1000 degrees Cent. or more for a period of 40 hours in an atmosphere of nitrogen at an increased pressure. According to the results of Jurisch, Hurum, and Oberhoffer and Heger, nitrogen diffuses into the steel and reaches a limiting concentration depending on the pressure. Such samples would be large enough for heat treatment and mechanical testing, but would be free from blow-holes, etc.

<sup>59</sup>*Journal*, American Chemical Society, Vol. 79, 1901, page 291.

<sup>60</sup>*Ibid*, page 1245.

## RELATIONSHIP OF BALL QUALITY TO BEARING LIFE

BY H. G. FREELAND

### *Abstract*

*This paper describes some of the important fundamentals governing the design, manufacture, application, and care of bearings.*

*The author points out the necessity of using a high grade steel for the manufacture of the balls and ball races; and also outlines the methods used in inspecting the steel and the finished product.*

*Steels that contain certain defects are not suitable for bearings and the author has discussed these factors.*

THE development of the ball bearing industry, had, as its incentive, the necessity for bearings with a lower coefficient of friction than that of the plain or journal type. Friction is the resistance to motion offered by two surfaces in contact. This resistance consumes some of the energy we desire to be used in doing useful work. The supplying of this energy is costly, especially when a large percentage is used in destroying plant machinery. This destructive energy is expended in fatiguing the metals composing the bearings and ultimately imposing unnecessary stresses on other parts. A few of these manifestations, their causes and effects, will be considered.

### THE STUDY OF BEARING SERVICE

The first bearings, which were cup and cone type, were used in bicycles. The speed of rotation was slow, and the loads light. Naturally, these were more satisfactory than a plain bearing, in spite of their defects. Their success in this particular application caused engineers to believe that balls could be used for higher speeds and greater loads, but their hopes were not realized until failure had been encountered, definite research made, and the requirements for a successful bearing service studied.

A paper presented before the Toronto Chapter of the Society. The author, H. G. Freeland, member A. S. S. T., is metallurgist with the Hoover Steel Ball Co., Ann Arbor, Mich.

They found that any type of steel would not do for balls or bearings, and that the balls must be true spheres and of uniform size to a high degree of perfection, defects produced during production and at the steel mills must be eliminated. Also, that special steel must be procured for ball races and that their construction must comply with definite requirements. They also found that the requirements governing service under thrust and radial loads must be complied with.

Of the various types of bearings we now have three: plain, roller and ball. The latter type is the one we desire to consider at this time.

The greatest demand for bearings comes from automobiles, then plant machinery and, finally, sundry applications.

Some of the applications for bearings in automobiles are as follows: crankshafts, camshafts, change gears, front and rear hub, and steering gear.

For plant machinery bearings are used in machines for production purposes, motors and dynamos, line shaft bearings, and cranes.

For sundry applications of bearings we have the following: hoisting jacks up to 200 ton capacity, swivel bearings on freight cars, elevators, airplanes, and under turret guns.

It would be useless, if not impossible, to enumerate all the different applications of bearings, so widespread has their use become. The thing which concerns us most is the type of service imposed by a given application. This can fundamentally be divided into two classes: radial and thrust.

#### DIFFERENT TYPES OF LOADING BEARINGS

If the load is to be supported at right angles to the shaft a radial bearing is needed; if parallel to it, then a thrust bearing should be used. In some cases a bearing is required to withstand both types of loading at the same time. Then the pressure on the bearing has a direction which is the resultant of two forces. Therefore, the ideal bearing is one which will prove efficient and durable under any of the conditions just cited. The life of a bearing or the service that should be expected of it is a matter of opinion.

It is only because we have to a great degree reduced friction

and by so doing reduced wear that we have adopted, to such an extent, what we now term anti-friction bearings. The more uniform the wear, the less accumulative is the action.

The wearing out or failure of a bearing may be brought about by the fault of the purchaser or the manufacturer. Therefore, a few of the things which should be borne in mind when selecting bearings, or passing judgment regarding the service rendered, will be discussed.

The manufacturer of ball races must, first of all, buy the right type of steel and the best possible grade. The best practice at the present time is to use a steel having a carbon content of 1.00 per cent and chromium between 1.25 and 1.50 per cent. This should be an electric furnace or crucible product. Case hardened bearings are not permissible where service under exacting conditions is required. Case hardening produces a shell of high carbon steel on the surface of the product which tends to flake off under vibratory stresses at heavy loads. The surface is also brittle, owing to its high carbon content directly at the surface. Remember, that when the surface of a race or a ball is defective, the bearing is doomed. The metal must be highly elastic without being brittle.

The races must be of heavy enough section to possess the required strength and rigidity. The shoulder or shoulders should be deep enough to furnish support to the area of the ball surface supporting the load, if the bearing is of radial type and is expected to carry some thrust.

The curvature of the raceway should have a radius a little greater than that of the ball, while not close enough to cause binding when the balls are expanded by the pressure they are supporting. This will give a minimum unit of pressure per unit of area of contact, when the bearing is under a given load. The radius of curvature for the races is usually 52 to 53 per cent of the ball diameter. If the axis of rotation of the balls is at an angle to the shaft, which it is when a thrust component is present, the balls must be considered as cones. Here mechanics require that the apex of the cones meet the axis of the shaft. In other words, the tangents at the points of contact, extended, must meet the ball axis at one point in the shaft axis, in order to insure true rolling motion. The designer of the bearings should make due allowance for this, in order to reduce spinning and subsequent grinding to a minimum.

One of the first things that should be considered is the distribution of the load. The pressure that a ball can support is directly proportional to the area of the contact surfaces at a given time. This area increases with the pressure. If the pressure per unit of area at a given point exceeds the elastic limit of the steel a permanent deformation of the metal takes place. Flatted spots on a ball make a noisy bearing, but more serious than this, the flatted ball in some positions will not support its full share of the load, thus overloading the adjacent balls and through them the race-way. The irregularities on the ball surface cause vibration and hammering, which at high number of revolutions per minute is a very destructive force. This point brings up the problem of bearing looseness.

The looseness of a rotating bearing causes the balls to change their axis of rotation from time to time, inducing some sliding friction with its attendant evils. Vibration in this case is more potent, tending to fatigue the steel.

The pressure that a ball can support is directly proportional to the area of contact with the races. Therefore, where the surfaces are planes, furnishing the minimum area of contact under load, they are incapable of safely carrying the pressure which can be imposed upon a bearing whose ball path conforms more closely to the curvature of the ball.

With reference to the bearing, where the bearing surface of one of the races is flat while the other possesses a curvature conforming more closely to that of the ball, the writer believes that he is correct in saying that this type is of little improvement over the one just cited. One of the contacts supporting the load possesses an area much less than the other, and as the pressure per unit of area under a given load spells success or failure, we can readily conclude that this bearing is little, if any stronger, than one in which the balls revolve between flat plates. It is wisest to use a bearing whose race path conforms quite closely to the curvature of the balls. The pressure is then distributed over the maximum possible area without causing the balls to bind during rotation, and this means the minimum pressure per unit of surface, thus over-strain for a given load is reduced to a minimum.

The supporting capacity of a ball is also directly proportional to its size and increases as the square of the diameter.

From this we see that it is wisest to use as large a ball as possible and that may be consistent with other factors.

The supporting capacity of a bearing increases with the number of balls carrying the load. It is, therefore, the best policy to use as many balls as convenient, remembering that in a loose radial bearing it may occur that only one ball is carrying the load. Therefore, the bearing should be so assembled that the parts fit snugly without binding; that the principle of rotation be followed in the construction of them so that wear is reduced to a minimum, and also that the user protect the bearing against grit and dirt, so as to avoid the grinding action which must necessarily ensue if material of abrasive character is admitted into the bearing, and in addition to this he must keep the bearings well lubricated.

It is quite possible that under some conditions one ball may support the whole load for a short period of time, and that this may occur in the case of the radial, radial thrust, or thrust bearing. It is, therefore, a good policy to allow a good factor for overload because in addition to this the maker of bearings never knows the abnormal strain which may be imposed upon them by the user. One of the most important requirements for balls, is that they must be true spheres and have the least possible commercial variation in size between them. It is the best practice not to use balls whose total variation in size is greater than one ten-thousandth of an inch, while the spherical accuracy should be within one twenty-thousandth. In order that the best results may be obtained it is just as necessary that the surface of the raceways should be free of all surface defects, whether attributable to material or processing, such as grinder marks and scratches; also that the ball path be concentric to a high degree of accuracy, as it is to require a ball of such a high standard of perfection.

If the type of bearing is such that the balls will tend to roll on two axes, spinning and the resultant friction ensues. In many angular bearings this is so, and in many bearings of this type centrifugal force at high speed tends to induce wedging. A three-point bearing represents a compromise between rotation on two axes at once, which induces sliding friction.

In actual practice the axis of rotation of this bearing is at an angle to that of the shaft and, therefore, should follow the law governing the rotation of a cone. When a ball is under press-

ure the load is supported not by a point but by an actual aerial contact, the shape of this contact depending upon the form of the supporting surface of the race. The tangents of the supporting surfaces do not lie in a direction normal to that of a cone. One of the lines touching the points of contact is a cord and not a tangent.

In the case of the four-point bearing, if used radially, might respond quite similarly to a roller whose sides were parallel, being subject to misalignment from the same cause (producing ball spinning) that would apply to a roller. The contact surfaces lie at an angle to the axis of rotation which means that any irregularities of the bearing surfaces, both at the surface and caused by any variation of the elastic properties at different points of the path, will cause a change in the axis of rotation, thus inducing spinning and grinding with the result that subsequent wear will tend to induce wedging. If used as a thrust bearing, these faults are greatly amplified, owing to many reasons, one of which can be seen if the direction of the tangents at the points of contact is noted. It will be seen that the lines connecting with the center of rotation in this case are chords and not tangents, as is required for correct rolling. In the thrust application of this type of bearing at high rotary speed, centrifugal force will cause most wear on the contacts farthest from the axis of rotation of the bearing. This will rapidly throw the whole system out of balance, while adjustment, if it were possible to be correctly made, might compensate to some small degree for irregularity in the case of the three-point bearing, but it is out of the question in this case.

While we are on the subject of adjustment it might be well to say that in the case of manual adjustment we have no means of knowing when a bearing is correctly adjusted to meet the requirements of true rolling motion. The probability is that the bearing, if adjusted with a wrench, for instance, will possess a high thrust component even though the load it may be expected to carry in transmitting power is zero. This means that the bearing may be readily overloaded in service, although supposedly carrying a pressure well within its rated capacity. Besides this adjustment, if necessary on account of wear, will probably alter the axis of rotation sufficiently to induce sliding friction. It is possible for adjustment to be made to compensate for wear, but this must

be automatic; in other words, the bearing must so be constructed that as the wear takes place the areas supporting the load will retain the correct relationship to the axis of rotation.

It will be seen from the above consideration of bearing types, that any condition which causes grinding or wedging and, thereby, wear and friction, shortens bearing life.

The surfaces of the ball path must be elastic without being brittle. They must not permanently deform under the maximum load imposed on them. They should be lapped until free from all defects, such as those left from previous processings. The surface of the races are weakest along the direction of the original stock. Therefore, the steel should be as dense as possible, because it is constantly springing up and down as the balls roll over it, and where the pores are close to the surface they are easily perforated.

This may be verified by examining an inner race which has failed. The inner race must be wide enough to furnish and give a firm seat on the shaft and it is wise to grind the shaft where the inner race will seat. The use of a light driving fit for the inner and a sucking fit for the outer race is recommended. The bore of the inner and the surface of the outer races must be concentric, so also must the bore of the housing. Nothing must be done which will tend to strain the bearing when mounting it. It must be protected from moisture, acid and dirt by correct housing. It must be oiled liberally with a good neutral mineral oil, using an oil of lower viscosity for high speeds. The reason for discussing these factors concerning bearings is apparent when we consider their ultimate effect on ball life. Whether the quality of a ball be good or bad, there are potent agencies at work to destroy it, having as their sources either defective bearings, misapplication or abuse in service.

Before leaving the subject of bearing design it might be well for us to consider for a moment the retainers. The use of these is to keep the balls correctly spaced in spite of any pressure which might be induced through irregularity of the race, surfaces, etc., which would tend to alter the distribution of the load or induce friction through the contact of the surfaces which are rotating in opposite directions. The retainers should be as light as is consistent with necessary strength and rigidity. They should be balanced and the section in contact with the balls should be as near

as possible to the point of minimum surface speed. By this means friction is reduced without interfering with the correct functioning of the retainer. In designs where the retainer is in contact with the balls at points of their maximum surface speed the contact surface should be smooth and large enough to support an unbroken film of oil, as this will materially aid in reducing friction.

Balls are the moving element between the shaft and the surface supporting the load which renders it possible for us to substitute rolling for sliding friction. The same can be said of rollers. By this means we can save power and reduce upkeep.

The ball bearing which is most to be desired is the one which transmits the most power for the longest period of time at the least cost. The service rendered depends on the quality of the bearing, its adaptability to the particular application, the mode of installation and subsequent care. As balls form a part of the bearing their resistance to the forces of destruction determine in a great measure the success or failure of the bearing.

#### INSPECTION OF MATERIALS

Our advancement in the mechanical field is only possible through a careful and unbiased analysis of failures. When bearing failure can be positively attributed to the balls it can be traced most usually to some defect in the raw material.

Defects arising from production methods are not so numerous. We are now only considering balls of the highest quality, namely, those produced by makers of known merit, to meet the most rigid requirements of service. The writer knows of no logical excuse for using balls of inferior quality in bearings, where any value from a mechanical standpoint of quality is required.

Some of the serious defects coming directly from the steel mill, such as seams, pipes, decarburization, etc., were discussed by the writer in a paper read before the Detroit chapter of this society and published in *TRANSACTIONS*, Vol. 2, July, 1922, so we will not go into great detail here but only study briefly some of the chief defects and their mode of elimination.

Seams or surface defects have two sources, the rolling of the billets to rods and the defects arising from casting. The former are of more or less extended length and most often appear on the ends of the rods. They are generally more pronounced on one

end than on the other and quite often come in pairs. The only sure way to avoid trouble from this source is to inspect both ends of each coil of cold drawn wire and reject all coils showing this defect. In the case of cold drawn or hot rolled bar stock it is best to make a 100 per cent inspection.

The inspection in both cases is made after etching the coils or bars to remove the scale and surface metal. This is necessary to render the defects visible. This type of examination will also reveal surface defects arising in casting of the ingot. These defects are usually short and deep and are distributed more irregularly than the former type. As it is usually impossible to inspect coils 100 per cent, it is best to take a liberal sample and reject all coils manifesting this defect. Fortunately this fault does not often appear in wire. One of the reasons for this is the fact that the section of the hot rod becomes greatly reduced in its transformation into wire, thus decreasing the depth of these defects to an amount which insures their disappearance before hardening. Unremoved seams are accentuated during hardening while unremoved decarburized steel, blankets the metal below, so that its effect is amplified.

Careful inspection is necessary to insure against pipes that occasionally escape detection in the mill inspection. These can be seen in the normal fracture, except in cases of the smaller sizes of wire, when they can be more easily seen after hardening.

Decarburization has been conquered at the mill and so causes little trouble. This is tested for by hardening small samples and testing with a file. Samples are taken from the different shipments received and are chemically analyzed, but in most cases the composition seldom varies from the required limits.

In addition to these tests, it is necessary, for manufacturing reasons, to check up on the hardness of wire, the diameter of the stock, note its freedom from rust and scale, and in the case of bar stock, the condition of the cropped ends.

Besides the above we must guard against and cooperate with the mill in the attempt to eliminate internal seams. It may be called porosity, dirt, the effect of gas occlusions, or what you will. It is there, sometimes more, sometimes less, and we are not positive at any time that the steel is free from it.

This type of defect is of serious character and affects decidedly the quality of any product made from steel. Internal

defects, such as the seams just mentioned, reduce the load carrying capacity of the ball, and when close to the surface form a nucleus for failure in a similar manner to that described when explaining the effect of porosity in race steel. The surface metal will crack when under sufficient pressure and flaking will result. Unremoved seams furnish the most prolific cause for flaking, while some other failures manifest themselves in the same manner but are the result of metal lapped on the ball during forming, or of pipes. The first and more usual manifestation of ball failure is the type just described, namely, flaking, while some balls do break; this is usually a secondary result, following flaking, which produces an uneven distribution of the pressure, amounting to overload, that causes the balls ultimately to burst. The same thing is sometimes accomplished when sections of the race path flake away. The pressure which a ball is expected to carry under normal conditions is usually such a small fraction of its actual crushing strength that unless the ball is actually fire-cracked or abnormally imperfect in some other way it will most usually flake before it will burst.

It is essential that the surface of a ball shall be uniformly hard. If a ball deforms permanently under load it will possess a flat at that point. When in the right position during rotation of the bearing this ball will fail to carry its necessary share of the load, which results in an uneven distribution of the same, while in addition to this it will cause hammering, owing to the fact that at times it is not in contact with the bearing in a normal manner. This creates vibration, which aids in fatiguing both the ball and race surfaces.

In order that balls shall be satisfactory in bearings, it is necessary that they should possess none of the defects which have just been discussed. Therefore, the fundamental requirements of good balls are that they shall be made of a good grade of clean steel, heat treated so that the surface is of uniform hardness, sufficient to support the load imposed upon it, without permanent deformation, while the structure should be as near as possible, uniform throughout. These essentials are aided by increasing the chromium content of the steel, as the ball sizes increase, and using a carbon content in the neighborhood of 1 per cent. The balls should be tempered in oil in such a manner that internal strains are relieved as far as possible without reducing the resistance of

the steel to deformation. They should be free from concealed surface defects. This can only be accomplished by correct inspection of the raw material and proper methods of manufacture.

The photographs of Fig. 1 show remnants of seams remaining in turned, cold formed and forged balls.

The ball on the left in photograph failed in a bearing test. It will be noted that flaking started from a seam. The next ball

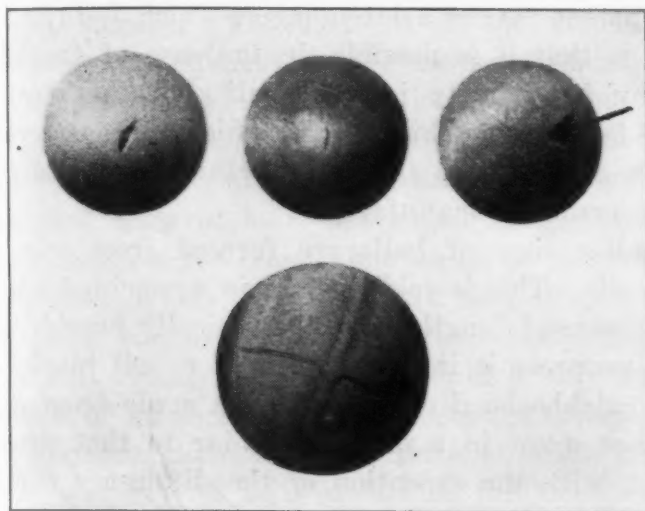


Fig. 1—Steel Balls Showing Defects which are Due to Seams in the Steel.

was not tested but shows a nucleus of the same type from which failure would start. The right hand ball shows an internal defect. This was below the bar surface and not in the region where pipes usually appear.

Referring to hardness, we can state that balls having a Brinell hardness number over 600 (using a 10 millimeter ball, 3000 kilograms pressure), whose surfaces may be just caught but not cut so as to flat by a fine Swiss file, has proven satisfactory.

The best grade of balls should not vary in sphericity over one-half of a ten-thousandth of an inch, while the maximum variation between the balls themselves should not exceed one ten-thousandth of an inch. The surface of the balls should be highly finished to such a degree that they are entirely free from any machine marks or scratches visible to the eye.

A brief summary of the fundamental operations in the production of balls may be of interest. The steel used in ball pro-

duction is purchased under very rigid specifications, particularly as to surface defects. This is essential to prevent accentuation of any defects during the forming operations and in order to reduce the amount of excess stock that it is necessary to remove from a ball blank in order to insure its being free from defects. Each shipment of steel has to pass a preliminary inspection before it is released from the car. It then receives a 100 per cent inspection, as previously described. Each lot of wire or rod of a given size and shipment carries a lot number, which follows it through production, so that it is possible, in the case of trouble arising, owing to any irregularity in the quality of the steel, to trace the material back to the shipment in which it was received. This is not only a great aid to the manufacturer, but assists the mill in rectifying errors in manufacture.

The smaller sizes of balls are formed from wire which is received in coils. This is cold pressed in a machine which shears off a slug of correct length and automatically carries it between dies, which compress it into the form of a ball blank. Sizes of balls in the neighborhood of one inch are made from cold drawn rods which are upset in a manner similar to that described for cold pressing, with the exception of the difference that the bars are heated in furnaces, previous to the operation, so that the slugs are hot sheared and the blanks are hot pressed.

The larger sizes of balls are made from hot rolled bar stock, the slugs being sheared hot and the ball blanks formed under a drop hammer. The ball blanks of various sizes are then dry-ground to remove the major portion of excess stock, leaving enough stock on the ball to take care of any scale which may be formed during subsequent heat treating operations and what is required to finally leave the finished surface of the ball without machine marks, scratches, or flats.

The balls go from the dry grinding department to the heat treatment department, where they receive the necessary heat treatment and are finally oil tempered.

After this the scale is removed from the balls by tumbling them in barrels with abrasive for a short period of time. The smaller sizes are then sent to the Hoffman machines, where they are reduced to within a few ten-thousandths of their finished required diameter. They then receive a lime finish after leaving the Hoffman machine; are carefully cleaned and polished

in leather to remove any moisture from the surfaces and are delivered to the inspection department for examination.

The larger sizes of balls are oil-ground in special machines, and then burnished, after which they also appear in the inspection department. Here they are first gaged as to size and then receive an individual inspection by experts, who pick out all defective balls. Following this they are packed, after being immersed in a specially compounded grease, which acts as a rust preventive during shipment and storage. The surfaces of the finished balls are sensitive to oxidation, therefore, they are never handled with the bare hands after entering the inspection department, but operators use gloves to prevent the balls becoming attacked by the moisture and acid which are ever present on the hands.

The smaller sizes of balls are gaged in gravity gages. In this machine they are fed from a hopper on to two hardened steel gage blades, down which they run until they drop between them into tubes which convey them to their respective compartments. These gages will readily separate balls which vary less than one ten-thousandth of an inch in size. The better grades of balls are always gaged more than once to insure absolute uniformity to size. The larger sizes of balls are gaged individually by the use of minimeters.

In the use of the minimeter for gaging balls, the balls and their master balls are immersed in oil several hours before they are to be measured, and each ball is gaged immediately after being removed from the bath. This automatically takes care of any temperature changes, which might create a serious error in case of balls of larger size. The master balls are those whose sizes have been accurately determined by the Bureau of Standards.

While on the subject of inspection, it should be said that shop inspectors carefully check up the quality of the product at each stage of production. These inspectors are responsible to the laboratory department and not to the production department. For example, the inspector checks the blanks from all of the forming machines each hour, so that should defective material have been missed by the laboratory at the time of examination of a given shipment, it is found and eliminated before useless fabricating expense is involved. This also reduces the chance of defective balls reaching the final stages of production and inspection and thus by any chance becoming mixed with the good balls being shipped.

In case defects arising from stock quality or processing are found, the machine is stopped and the fault rectified. The balls are either removed to another department where they are subsequently reduced if the defect be small, or else they are scrapped immediately. Another case of inspection, which is of interest, is that of the hardening room. Every pan of balls from each hardening furnace is checked by an inspector for crushing strength, surface hardness and quality of fracture. This gives definite information regarding the control of the furnaces and insures a uniform product.

#### SUMMARY

The writer has attempted to briefly describe some of the important fundamentals governing the design, manufacture, application and care of bearings. It will be seen how the quality of races and balls must be of the same high standard to insure durability. Defects in either will bring about the destruction of both. In the final analysis, it appears that a large amount of our future improvement will depend on our knowledge of the characteristics regulating the behavior of that thin film of metal directly at the surfaces of raceways (ball path) and of balls. What takes place during rotation under various stresses is of prime importance. We are presuming that the laws governing rolling motion have been complied with and the bearing is suited to the application, and that reasonable care is exercised during service.

The steel must be of a type and structure which offers greatest resistance to fatigue and vibratory stresses. This requires greatest possible freedom from internal defects, while the composition and heat treatment of same must be such as to insure maximum elasticity with a minimum of brittleness.

A great many of the ball and bearing manufacturers not only have laboratories for the control of raw material and production operations, but also for research. Some of our national universities have departments of applied science which are assisting in the solution of industrial problems. Their cooperation and research have been of inestimable value to both the industries and nation as a whole.

It is essential that ball and bearing manufacturers desiring to render the greatest possible service must cooperate directly with the steel mills in order to procure the best possible raw mate-

rial for bearing production. They must constantly be doing research work on the properties of different alloys with a view of improving their product, if possible.

Some of the problems which need careful study at the present time are:

1. Means of positively determining the amount of impurities and internal defects in steel, such as gas and non-metallic inclusions, hair lines and porosity, their effect, and means of elimination.

2. Relationship which different percentages of a given element bear to its resistance to fatigue. For example, chromium, vanadium, molybdenum, etc.

3. The sizes and contour of the actual supporting areas of balls in their races when under various loads and conditions.

4. Relationship of temporary and permanent deformation to the stresses producing them, which must naturally cause considerable variation in the contact areas, and thus the load supporting capacity of the bearing at different speeds.

5. The effect of composition and also curvature of the surfaces when in contact under pressure, on the resistance to rupture of the fibers of the metal, as exemplified by the broken contact areas and often radial cracking which occurs when two bodies of steel are pressed together, such as two balls, or a ball and a plain surface.

6. The effect of different methods of forming and of heat treatment on strength and durability.

If a bearing under consideration should comply with the laws of rolling motion and other essentials you will see that a little more definite knowledge about what actually takes place at the contacting surfaces when revolving under a load would be of great assistance in determining safe working capacities.

It will be seen from the considerations we have given the subject of the relationship of ball quality to bearing life that the behavior of each element composing the bearing, as well as the adaptation, and service imposed upon it are closely interlinked, and that future advances in the industry, as well as the supply of the best quality of product, is directly dependent upon the close cooperation of the ball manufacturers, bearing manufacturers, those producing raw material for the same, and the ultimate consumer.

## TREND OF DECREASE IN TENSILITY AND BRINELL HARDNESS BY TEMPERING

By E. J. JANITZKY

### Abstract

*This paper offers a mathematical equation for interpolation of physical properties, such as tensile strength and Brinell hardness, as obtained in tempering of hardened steel, when three experimental observations are given.*

IN analyzing the trend of the decrease of such physical properties as tensility and Brinell hardness by tempering hardened steel, one comes to the conclusion that the decrease with increasing tempering temperature, up to the critical point, follows an equation of the order—

$$X = \frac{P}{\left(\frac{P}{p} - 1\right) \left(\frac{t^0}{T^0}\right)^n + 1}$$

X denotes the tensile strength or Brinell hardness at any tempering temperature between P and p, maximum and minimum.

P denotes the tensile strength or Brinell hardness of hardened but not tempered steel (maximum).

p denotes the tensile strength or Brinell hardness of steel quenched and tempered near, but below the critical range (minimum).

$t^0$  denotes the tempering temperature corresponding to X.

$T^0$  denotes the tempering temperature corresponding to p.

It is obvious that—

$$n = \frac{\log(P-x)p - \log(P-p)x}{\log t^0 - \log T^0}$$

and that in solving “n” a third experimental observation (x) is required in order to interpolate the values between the tempering range from atmospheric temperature, which, for the sake of simplicity, can be set at 0°, up to the critical range.

In spite of the great amount of investigational work which has been done upon the hardening and tempering of steel, complete representative curves, starting with the hardened but not tempered steel, and showing physical changes through which the material passes as the drawing operation proceeds, are rather rare

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in technical literature. This may be ascribed to the machining difficulties encountered with the heat-treated bars, especially in alloy steels which have not been tempered or have been tempered at low temperatures. In this case the test specimens are usually machined to the standard tensile size plus a grinding allowance

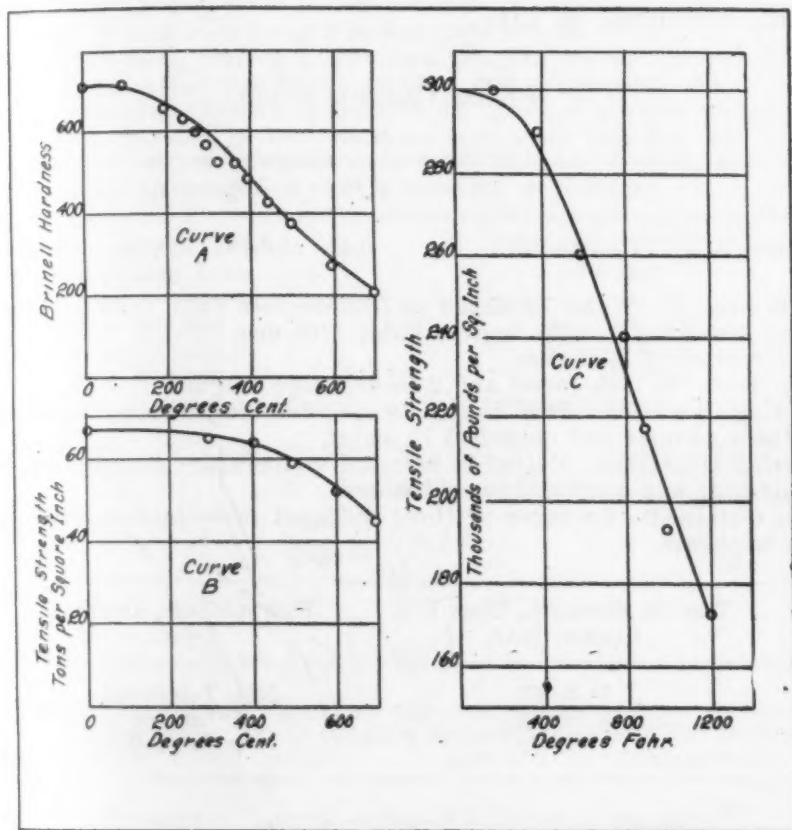


Fig. 1—Curve Showing the Decrease in Physical Properties with Increasing Tempering Temperatures.

prior to heat treatment, whereas the easily machined bars are left in the original size. These variations will obviously disturb the real trend in the drawing operations.

The question of a difference in findings of various investigators with regard to the behavior of physical properties at low tempering temperatures, which, however, does not seem to interfere appreciably with the general trend of the formula, is omitted by the writer.

A comparison of calculated and actual results is exhibited

in the two following examples, one of a 0.45 per cent carbon steel and the other of a 0.48 per cent carbon, chromium-vanadium steel. The former is taken from "Report No. 75 of the British Engineering Standard Association—1920," and the latter from a paper entitled "Impact Tests," which was read by H. J. Stagg before and, later, published by the Steel Treating Research Society of Detroit, Michigan, in 1917.

### PLAIN CARBON STEEL

|                | C.   | Mn.  | P.    | S.   | Si.  |
|----------------|------|------|-------|------|------|
| Analysis ..... | 0.45 | 0.78 | 0.025 | 0.02 | 0.32 |

Heat Treatment: Water hardened at 1600 degrees Fahr. (870 degrees Cent.) and drawn up to 1290 degrees Fahr. (700 deg. Cent.).

Size of Section: 1½ inches.

Tensile Test: ½ inch round and 2 inches gage length.

Hardening Operation: Steel heated to specified temperature, maintained for fifteen minutes and quenched in water.

Tempering Operation: Raised to selected temperature, maintained for one-half hour and quenched in cold water.

Results Obtained: Averages of three different investigators, each working in triplicate.

| Tensile Strength, Tons Per Square Inch | Temperature, Degrees Cent. |
|--|----------------------------|
| P = 67                                 | Not Tempered               |
| p = 45                                 | T° = 700                   |
| x = 59                                 | t° = 400                   |

$$n = \frac{\log(67 - 59)45 - \log(67 - 45)59}{\log 400^\circ - \log 700^\circ} = \frac{1.01827}{0.24304} = 4.2$$

$$X = \frac{67}{0.49 \left( \frac{t^\circ}{700} \right)^{4.2} + 1}$$

| Tempering Temperature Degrees Cent. | Tensile Strength—Tons Per Square Inch Actual | Calculated |
|-------------------------------------|--|------------|
| Not Tempered                        | 67   | 67         |
| 300                                 | 65   | 66         |
| 400                                 | 64   | 64         |
| 500                                 | 59   | 60         |
| 600                                 | 52   | 53.5       |
| 700                                 | 45   | 45         |

## CHROMIUM-VANADIUM STEEL

|                | C.   | Mn.  | P.    | S.    | Cr.  | V.   |
|----------------|------|------|-------|-------|------|------|
| Analysis ..... | 0.48 | 0.85 | 0.009 | 0.007 | 1.26 | 0.18 |

Heat Treatment: Oil hardened at 1650 degrees Fahr. (900 degrees Cent.) and drawn up to 1200 degrees Fahr. (650 degrees Cent.).

Size of Section: 0.010 to 0.015 inches oversize of standard tensile test.

Tensile Test:  $\frac{1}{2}$  inch round and 2 inches gage length.

Hardening Operation: Raised to selected temperature in oil-fired furnace, held at temperature five to ten minutes and quenched in oil.

Tempering Operation: Drawn in liquid bath of oil, a mixture of potassium and sodium nitrates, or lead, as the temperature required, and held for twenty-five to thirty minutes.

Results Obtained: Averages of closely agreeing duplicates.

Tensile Strength, Pounds  
Per Square Inch

Temperature, Degrees  
Fahr.

P = 300,000

Not Tempered

p = 172,000

T° = 1200

x = 218,000

t° = 900

$$n = \frac{\log(300,000 - 218,000)172,000 - \log(300,000 - 172,000)218,000}{\log 900^\circ - \log 1200^\circ} =$$

$$\frac{0.29638}{0.12494} = 2.37$$

$$X = \frac{300,000}{0.74 \left( \frac{t^\circ}{1200} \right)^{2.37} + 1}$$

Tempering Temperature  
Degrees Fahr.

Tensile Strength—Pounds Per Square Inch  
Actual Calculated

Not Tempered

300,000

300,000

200

300,000

297,000

400

290,000

285,000

600

261,000

262,000

800

240,000

234,000

900

218,000

218,000

1,000

193,000

202,000

1,200

172,000

172,000

No experimental results were given for a "not-tempered" chromium-vanadium steel specimen, so the results shown for tempering at 200 degrees Fahr. were taken as the maximum, P. The variation, however, in actual testing would be negligible.

Fig. 1 illustrates diagrammatically the trend of decrease in physical properties as tempering proceeds, the full-line curves

representing the calculated values and the circles the actual experimental values as found by the investigators.

Curve A represents the Brinell hardness values at surface locations of a  $\frac{1}{2}$  x 1 x 6 inches tool steel specimen, analyzing 0.95 per cent carbon, 0.22 per cent manganese and 0.24 per cent silicon, which was quenched in water from 1475 degrees Fahr. (800 degrees Cent.). These results were taken from an article by Howard Scott and H. Gretchen Movius, entitled, "Thermal and Physical Changes Accompanying the Heating of Hardened Carbon Steel," which appeared in the September, 1921, issue of TRANSACTIONS.

Curves B and C represent the tensile strength values of the plain carbon and chromium-vanadium steels, upon which the two preceding examples were based.

In concluding, the writer hopes that the method outlined for determining the physical properties obtainable at various tempering temperatures may arouse interest, so that more light will be thrown on the problem.

## THE HIGH POINTS IN THE MANUFACTURE AND WORKING OF STEEL

BY L. F. JOHNSON

### *Abstract*

*This paper briefly outlines the manufacture and mechanical working of steel.*

*The author points out the essential differences between the acid and basic open hearth practice.*

*The working of the heat and the methods of producing a satisfactory slag are discussed, as well as the methods used in controlling the elements in the bath.*

*The author also discusses drop forgings.*

IN its manufacture, steel necessarily has its inception in the blast furnace. It is here that the ores are reduced to metallic iron. This metallic iron is known as pig iron. Due to the low strength of pig iron, especially its low degree of ductility and fatigue value, further refinement is necessary and this is accomplished either by the Bessemer, open hearth or electric furnace method of steel production.

Due to the fact that the Bessemer process of steel making has decreased in percentage of the total production of steel to such a low point, and that the volume of production so predominates in favor of the open hearth process, we will confine this discussion to the making of steel by the open hearth furnace process.

The modern steel plant today is either self-sustaining or is dependent upon outside sources of pig iron supply. The self-sustaining plants are those which are equipped with their own blast furnaces. This feature is important in the open hearth department, because a self-sustaining plant has or should have absolute control of the quality of the hot metal supplied to the open hearth furnaces. Likewise, increased efficiency is obtained due to the fact that in the self-sustained plant the pig iron is charged in the molten condition into the open hearth furnace, whereas with the other method, the pig iron is charged into the open hearth cold. By charging hot metal, the furnace time per ton

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of steel produced is reduced. Plants that purchase their pig iron on the outside are often forced to either take pig iron of a grade which may cause trouble in the open hearth furnaces, or are forced to absorb various handling charges in case of rejecting this purchased product.

The equipment in addition to the blast furnace and open hearth furnaces consists of rolling mills of various types and sizes, special duty mills, and such power and equipment as is necessary for the maintenance of several units. Some mills are equipped with expensive and heavy forge departments. However, these are not generally considered a part of standard steel plant equipment.

The open hearth method of making steel is divided into two classes: the acid and the basic. The difference consists principally in the refractory lining of the furnace itself. The acid process requires a furnace lining, having acid characteristics when hot. The bottom is usually made of sand. The basic process requires a furnace lining, using some type of basic refractory such as dolomite, magnesite or other calcareous material which will sinter to a high-temperature resisting coating.

The acid process consists of melting suitable scrap and pig iron in an acid-lined furnace, usually without the use of a slag-making material. Usually the only slag which occurs in the acid process is that which is washed from the banks and the bottom of the furnace, and from the reduction of such impurities in the iron as are oxidized by the action of the flame in melting down. Occasionally, it is necessary to add some silica sand where evidences of basicity in the slag are strong enough to indicate that an attack on the furnace lining is taking place.

The basic process consists of melting suitable scrap and pig iron and a sufficient amount of limestone to absorb the metalloids of the charge. This limestone forms a slag which covers the steel while it is being worked. The charge consists in, first, distributing the limestone over the bottom of the furnace and upon this the necessary amount of ore to reduce the carbon of the initial charge, and to assist in the bringing up of the lime on the lime boil. The scrap is then charged and it is at this point that the difference in the character of scrap is observed.

Every open hearth man prefers good scrap to bad, due to the fact that working a heat with good scrap is much easier than

otherwise. By good scrap is meant a heavy melting type wherein the melting down involves a continuous liquification without the production of unnecessary scale such as is incident to the fuel attack on lighter materials. The chemical analysis of the scrap, especially in respect to the content of phosphorous and sulphur and alloying elements, must be closely controlled. Light scrap as a general rule, such as tin and sheet scrap, usually crowds a furnace due to the large amount of voids. Such scrap has a tendency toward flame deflection, which may be disastrous to the roof and side walls of the furnace. Also with this type of stock, the material scales excessively as the temperature rises and thus causes metallic losses. Punchings and scrap of this character have a tendency toward what is known as "balling-up," that is, after the entire charge is melted down, a big ball or "nigger head," as it is called by furnace men, will be found unmelted in whichever end of the furnace this material has been charged. This resistance to melting is due to the fact that a protecting coating of slag has so covered and permeated the mass of scrap, that the attack of the major molten body of steel is delayed. Upon completion of the scrap charge, the pig iron is added, generally in a molten condition. This is possible in modern plants due to the fact that each open hearth department is equipped with a mixer or reservoir wherein molten pig iron taken from the blast furnaces is stored for future charging into the various open hearth furnaces.

The melting down period immediately follows the charging. This, as a general rule, usually consumes about 60 to 70 per cent of the total furnace time for the heat. In hours this is probably 5 to 6 hours in the melting down period on carbon steels, and 6 to 8 hours on alloy steels. The time factor on this melting period depends first on the type of fuel, second, the method of application, third, the age of the furnace, in respect to the cleanliness of the regenerator chambers and fourth, the type of scrap charged.

Optical observations through the wickets will disclose when the charge has melted down. This observation will show when there are no evidences of unmelted scrap visible above the level of the slag. During the melting of the scrap, the ore fluxing with adjacent particles of lime causes an ebullition which continues until the major portion of lime resting on the bottom of

the furnace comes to the surface. The boiling of the ore facilitates the rising of such lime as has adhered, during charging, to the semi-viscous bottom of the furnace. As a general rule, the lime comes up in a body and it is on the completion of this that the actual working of the heat begins.

The ore, during its boil, has practically reduced most of the silicon in the pig iron and also some of the carbon, but not to a great extent, inasmuch as enough ore has been charged to continue this action, even after the rising of the lime. The lime, when it floats on the surface of the molten steel, is in large chunks and is somewhat hard. Occasionally it is necessary to use fluor spar to disintegrate these large lumps. This feature, however, is one which the melter must continually watch, due to the usual tendency on the part of a helper to rush the shaping of the slag by excessive additions of the fluor spar. Too early or overfeeding of spar may thin the slag causing a reduction in its basicity so that the metalloids which necessarily should be held therein, will be re-precipitated into the metal and either cause the loss of the heat or the addition of extra lime to build up an artificial basicity. This last resort involves a serious loss of time and possibly an inferior final product.

In working a heat, the shaping of the slag and reduction of carbon, manganese and silicon in the bath, is effected simultaneously. It is the usual custom for the open hearth melter to so calculate his charge that it will melt high enough in carbon after the action of the ore boil to allow the addition of small amounts of hard ore to effect such further reduction as is necessary for the heat. The additions of this type of ore implicates further boiling and this boiling, of itself, is conducive to a softening of the lime. After the slag blanket has acquired a sufficiently uniform thickness, the open action of the metal in its evolution spurts up through the slag with a scouring effect which tends to reduce the elements which we are desirous of controlling. This direct exposure of the metal to the flame through the slag also is continuously heating it up to a point where it will be possible to satisfactorily teem the heat.

Various tests are made by furnace men to determine both the chemical content and the temperature of the steel they are making. In estimating the chemical composition, a test bar is poured. After solidification and cooling, this bar is broken and the appear-

ance of the fractured crystals is an indication of the carbon content. The temperature of the open hearth bath of steel is usually estimated by judging the color of the metal as poured from a test spoon and by shaking a rod through the bath itself. The temperature, by the "rod shake," is readily detected by the character of the cut-off on the end of the rod. A sharp, square cut-off indicates a clean pouring temperature; a rat-tail end would indicate too low a pouring temperature.

The average heat when "ready to go," as is generally said, is considerably lower in the various elements than is desired or specified and it is therefore necessary to make up these deficiencies by the addition of various ferro alloys, or carbon to render the product of such chemical composition as is desired. For example, if the carbon were 20 points on the fracture and quick laboratory test, and 45 points (0.45 per cent) was desired it would be necessary to add 25 points of carbon. Likewise, if the manganese were 20, and 60 was specified, it would be necessary to make sufficient additions of ferro-manganese to make up these 40 points of manganese which were lacking.

Calculations of the amounts of hot metal or coal for the necessary carbon, and ferro-manganese additions for increasing the manganese content are simple problems in proportion. It is impossible, however, to use straight figures in calculating these additions, due to the fact that various conditions incident to the furnace itself, quality and character of the slag, the temperature and action of the metal, all tend to cause losses which are not calculable and are judged entirely upon the experience of the melter. These variables are so different that should a strange melter go from one plant to another and be able to correctly diagnose the percentage of elements in the test, he would likely miscalculate and lose the heat on off analysis. This is due to furnace conditions to which he is not familiar and to which he is not able to judge without personal experience on the furnace itself.

It is amusing to watch some of the older melters in their calculations of additions. Over a period of many years in various plants, the writer has had the opportunity to closely observe some of these "old timers," and it is remarkable, especially in consideration of their mathematical ability and non-observance of metallurgical laws, the success they obtain with their rule of thumb methods. As an example, we were making in a certain

plant, some high sulphur screw stock. The heat under consideration was approximately 100 tons and the sulphur in the bath ran about 0.04 per cent. It was our desire to tap a heat close to 0.075 per cent sulphur so the melter in charge inquired as to how much sulphur he ought to add to the bath of steel. As the writer had made the calculations for the furnace charge and had taken into account those oxidation losses in sulphur which he thought would be present in this particular heat the melter was given the figure for a sulphur addition on this basis. The melter immediately said that he thought that this addition would not make the heat according to specifications, and when questioned as to his reasons for this belief, he referred to an old notebook wherein he found a heat that he had made in the past in which he had made somewhat different additions to approximately the same charge in the furnace. When asked whether he had considered the difference in the furnaces, he answered by saying that he did not see where that made much difference. The result was that we compromised on our figures—this probably due to the various superstitions surrounding open hearth practice—with a result that the heat fell below both of our calculations. This example illustrates that it is possible to miscalculate the final composition of the heat both from a point of view of mathematical figures and from the point of view of the rule of thumb methods. A variable factor which caused certain losses which we did not appraise existed in this heat.

This feature of miscalculation is one of the reasons for many companies to hesitate in accepting orders for special or off standard analysis steels. The reason for this is obvious, because should the melter's calculation be erroneous, such a heat would not be acceptable and would remain on the banks to be ultimately turned back as scrap.

As a general rule, the open hearth melters and superintendents of today are of a high type and their percentages of miscalculations are low. The writer recalls figures obtained in one rail mill covering between 600 and 1000 heats and the percentages of loss on off analysis heats was less than one-half of one per cent. The average, however, in a production carbon steel mill will run conservatively about 5 to 7 per cent. These off heats on a carbon steel production mill are not necessarily scrapped, due to the elas-

ticity of application and great range of specifications that are used in the industry.

After the additions have been made and the furnace is tapped, the steel is poured into ingots of various sizes and types, depending upon the blooming mill in which it will be rolled or the press under which it will be worked, or on the ratio of reduction from the ingot to the finished product which is required by specification. The average steel mill ingot is a round cornered rectangular section of approximately 300 to 400 square inches. This would make an ingot approximately 24x24 inches on each face. Forging ingots are either flat-sided or fluted polygons with straight or tapered sides. The weights of ingots vary from 8,000 pounds to 400,000 pounds. Ingots as large as 400,000 pounds are usually made for armor plate for naval ordnance and can be cast by only two or three plants in the United States.

Upon completion of the pouring of the heat, the ingots are transferred to a stripping building where the molds are removed and the ingots themselves are then ready, depending upon calculated time-cycles, for charging into the preheaters or soaking pits. With some types of steel, principally the carbon types, it is possible to charge them directly from the stripper to the soaking pits. There are various types of alloy steels, such as carbon-vanadium, chromium-vanadium and steels which are affected more or less by air quenching that must be handled with extreme care due to the fact that should the cooling from the molten condition to the solid state and from the solid state down to a black heat be carried beyond certain cooling rates, various internal strains are set up which are likely to result in internal ruptures, generally of a transverse type, and necessitate a "time" charge.

Analogy is the chief method of arriving at the proper time cycle and while it is expensive it is the only form of solution to a problem of this kind. This is due principally to the fact that the variables in solidification from one ingot size to another, and the direction and intensity of cooling strains due to volumetric shrinkage are so diversified that a calculation of direction of strain against time is quite impossible. It has been found through this analogy referred to, that there is a certain zone wherein these strains and shrinkages seem to neutralize, and it is in this zone that such steels are charged into slow heating soaking pits and allowed to take a longer time to arrive at the proper rolling tem-

perature. In a recent paper by J. F. Harper, in *Mechanical Engineering*, the details of these fissures referred to are ably and graphically described.

In rolling practice, we have the first of "breakdown" mill which is called the bloomer. Next from the bloomer, we have the billet mill and slab mill. The billet mill takes care of bars for supplying the various finishing mills, and the slab mill takes care of slabs for furnishing the various plate mills. Various special duty mills, as for instance, the rail mills and sheet-bar or skelp mills, generally run into heavy tonnages and especially in the case of the rail mill, are supplied with their own bloomer or breakdown mill.

The various shapes or sizes that are rolled are familiar. The difficulties experienced in rolling are first, improper or careless heating, and second, mechanical defects in the steel, such as seams, slivers, off sections, over-fills and under-fills. These mechanical defects are generally handled without any great trouble. The problem of heating, however, is one which bears constant vigilance and is just as important to the product as the precluding of an over oxidized or gaseous heat by overheating in the open hearth.

Forging, in general, is either straight blacksmith work which includes anything shaped in open dies whether hammer or press, steam or hydraulic, or drop hammer work, which may be made in closed dies. Drop forgings are generally of small size and seldom include work weighing over 200 pounds or forging stock having a diameter of more than 5 inches. Drop forgings today cover an immense field, having replaced many mechanical parts which were formerly either gray iron or malleable iron castings. This is due to both the decreasing cost of forgings and the increase in strength demanded in the reduction of the cross section of these parts. Drop forged work is both interesting and intricate. The average mechanical work involved is exactness in die setting, speed in production and the general care of the production tools. The hammerman's duties are more or less routine and his caliber is judged from the exactness by which he carries out the foregoing factors. Metallurgical responsibility involves the choice of proper hammer for the job, the saving for any waste, whether from cutting lengths or excessive tong holes and the type and opera-

tion of heating furnaces. The greatest difficulties experienced in drop forging may be listed as follows:

1. Mechanical defects, such as die shifts, cold shuts and poor edgers, which may cause the rejection of forgings. These are easily corrected.
2. Insufficient furnace capacity for heating the steel.
3. Careless heating and overheating.

Insufficient furnace equipment is in a great many shops the most vulnerable point and this is due to the fact that in heating low carbon steel, less care and time of heating is required than on alloys of which in the average automotive drop forge jobbing shop now runs as high as 70 per cent of the total production. When alloy steels are charged into the heating furnaces and the same procedure is used as in heating carbon steels, invariably trouble ensues. Usually the stock becomes over-heated and at times even the burning of the product beyond recovery results. The metallurgist and heat treat superintendent knows what a large amount of unnecessary work is placed upon the heat treating department as a result of the over-heating of materials in the forge shop. While the critical points have not changed in the over-heated materials, the absorbing powers of the steel in total grain refinement or the breaking up of the large crystals formed by general or local over-heating is so reduced that it is difficult to correctly gage the heat treatment time factors, with the result that it is often necessary to re-treat such forgings. The writer is familiar with certain shops wherein improper layout and insufficient furnace capacity has reduced the individual capacity of each hammer and man by 60 per cent. This is indeed lamentable in these days of price competition and no doubt has contributed in no small share to the failure in the past year of more than 25 drop forging plants throughout the country.

Careless heating is due either to the insufficiency of furnace space or the lack of knowledge of the rate of heating of given sections and the heat absorbing capacity of the steel. As an illustration of this, a forge man may start a job using chromium-molybdenum steel and after a few impressions, complains that his production rate is too low for this "tough" steel, which under the hammer, he says, acts like rubber. The facts in the case are that while the material has more deformation resistance than straight carbon steel, the heating which is being applied, both in rate

and temperature, is the same as on carbon steel and as a result does not penetrate the core. The surface, however, may be too hot. The higher compressive strength of this alloy material reacts sensibly on the hammer piston and is interpreted by the operator in terms of "toughness." (The static ratio of alloys may be 4 or 5 to one times higher is the case of the carbon steel.)

Heavy forge work embraces a wide field and involves such work as marine shafting and engine parts, locomotive members, turbine forgings, high pressure steam boilers, chemical cracking tanks and down the scale of size into the more intricate small tools and parts. In marine work, we can place ordnance materials and equipment. The material used in heavy work probably predominates in the carbon steel grades, if we omit ordnance. The amount of alloy steel, however, is increasing and no doubt with the increase in weights, in new designs figuring from carbon steel values and the desire to decrease weight without sacrifice of strength, the alloy steels will have increasing demand as time goes along.

With the advent of alloy steels in the heavy forging business the necessity of more accurate forge heating control has become more imperative. In the shops where the making of heavy forgings has been done in a more or less perfunctory way with the use of carbon steel, it has been found that by the application of a higher grade of material, that higher grade men and higher grade handling equipment is demanded. Who would have dreamed of the technical man, who had never made a forging with his own hands, directing and having full charge of a hammer or press shop? Yet, today, there is not one of us who has either seen this transition or is cognizant at times of its necessity. The day of the older methods of chance and guess have passed and we find that the higher type of the men of the old school are readily conforming to modern methods and are even, in many cases, equipping themselves with metallurgical knowledge available either through correspondence or extension courses or through such societies as the A. S. S. T. Technical, common sense control is gradually remedying the over-heating, washed corners, under-heated cores and the use of hammers of insufficient capacity.

In forge practice, steel is received in either ingot, bloom or bar form. Specifications for heavy forge work generally require standard rations of reduction from the ingot to the finished forg-

ing and in some instances where major stresses are transverse or radial, specify a product all forged, which means that no rolling is permissible.

I believe it has been demonstrated to the satisfaction of a great many that this has been the cause of a great deal of trouble in the past and that present practice in certain shops has improved immeasurably in percentage due to the fact that control has been assumed and prosecuted over the type and method of heating ingots or blooms.

As a broad statement, and as a recommendation for large forgings, set forth in the specifications of certain producers, it is highly desirable that an hour per inch of thickness be given as a minimum for the average production heating for forgings. According to calculations as performed by Leeds and Law and later as expounded by E. J. Janitzky, a shorter time than an hour per inch can be satisfactorily used if the control is absolute and the human element is irreproachable—in other words, if conditions are 100 per cent in care. This, however, does not exist in the average production shop and the hour per inch is used to preclude any possibility of too rapid heating which can overcome all of the care taken in solidification toward the prevention of fissures and even result in the explosive separation of major portions of an ingot or billet.

Through analytical study, it has been found that in such shops as prosecute a careful and conscientious forge practice and retain more or less personal control of the human element, subsequent heat treatment to forged parts results almost in child's play and that the only factors necessary for heat treatment is knowledge of the critical range or temperatures at which to quench or normalize.

It is believed that the tendency on the part of all forge shops in which I come in contact is receptive to any suggestions conducive toward the improvement of their practice and that the general tone is one of co-operation with the steel manufacturers.

The offer of such service as the steel companies can give through their various metallurgical departments toward the proper and intelligent application of the steels used, is being more availed of as time goes on.

## DRAWING BY CONVECTION

BY J. W. HARSCH

### *Abstract*

*This paper describes an electric heating furnace used for tempering hardened steel parts. The furnace embodies several novel features, particularly the fan system, which provides a means of obtaining uniform temperature conditions throughout the furnace.*

*The author has illustrated the paper with several heating curves, which show the temperature condition on the inside of the furnace when charged with different types of loads.*

IN the application of the direct-heat<sup>1</sup> type electric furnace to the tempering of hardened steel parts or tools, its successful operation is limited by the nature of the work to be treated. Such a furnace can only operate satisfactorily where all of the parts under treatment are subjected to similar radiation and uniform convection from the furnace wall, and becomes inefficient with any type of loading which requires that heat be transmitted from one piece of work to another by re-radiation or conduction, that is, the furnace fails to operate successfully on a load composed of a large number of pieces, owing to the inefficient transfer of heat through the multi-cellular structure of the load. The result is that a serious non-uniformity is encountered throughout the load and extremely slow heating is necessary to prevent some parts of the load from overheating before the other portions reach the desired temperature. This slow heating introduces a wide variation in the time factor of the tempering process and, since time and temperature are interrelated in determining the final degree of temper, results in still greater non-uniformity in the work being treated.

In modern production methods the tempering of large quantities of work at the same time is necessary. This has resulted in the adoption, in a large number of cases, of an oil or salt bath in order to secure the desired uniformity together with high pro-

<sup>1</sup>Direct-heat type electric furnace is used to designate a furnace in which heat transfer is by radiation and convection and incidentally conduction.

The author, J. W. Harsch, is research engineer, Leeds and Northrup Co., Philadelphia.

duction rates. Either of these, if properly designed, provides a good degree of uniformity, but they possess certain inherent faults and do not lend themselves as readily to control as does the electric furnace. The cost of operation is high in the case of both the oil and salt bath from the standpoint of power consumed as well as the cost of oil and salt. The radiation losses from the open baths are large and may represent a considerable percentage of the total power consumed in the tempering operation. The use of either of the baths necessitates an extra washing or cleaning operation beyond that which is necessary with the electric furnace. In the case of the oil bath a fire risk is also present as well as undesirable working conditions.

With the salt bath one contends with decomposition of salt, fumes from the bath, and what is more important, the work must, necessarily, be introduced into a hot bath. This may be undesirable from the viewpoint of introduction of internal strains into work which may already be near the breaking point in this respect.

If, then, the electric furnace could be so constructed as to provide the necessary uniformity, it would seem to possess numerous advantages over other methods of tempering for a wide range of work. The writer wishes to make clear that the direct-heat type electric furnace is satisfactory for tempering operations, where properly used, but does not have the range of application desirable. In any case where it is used thorough exploration of the furnace for temperature uniformity should be made under actual working conditions, and in most cases non-uniformity of work can be eliminated by so using the furnace as not to exceed its capabilities for providing uniformity.

This paper describes an electric tempering furnace which has been so designed as to extend its range of application to the satisfactory tempering of work in large quantities on a production basis. The furnace is unique in that radiation has been almost entirely eliminated with the substitution of forced convection heating. This is accomplished by the circulation of air from the source of heat to the work. As a means of improving the uniformity the direction of circulation of the air is reversed at periodic intervals. This materially aids in the reduction of temperature differences through the load. Several furnaces of this type have been thoroughly tested under severe conditions and have been found to provide unusually good uniformity. The performance

of such a furnace is probably best shown by actual test charts, obtained under operating conditions, showing the temperature uniformity throughout the furnace.

Fig. 1 is a cross section showing details of furnace structure which have been worked out to permit the use of forced convection heating. In this figure the central portion, marked "basket

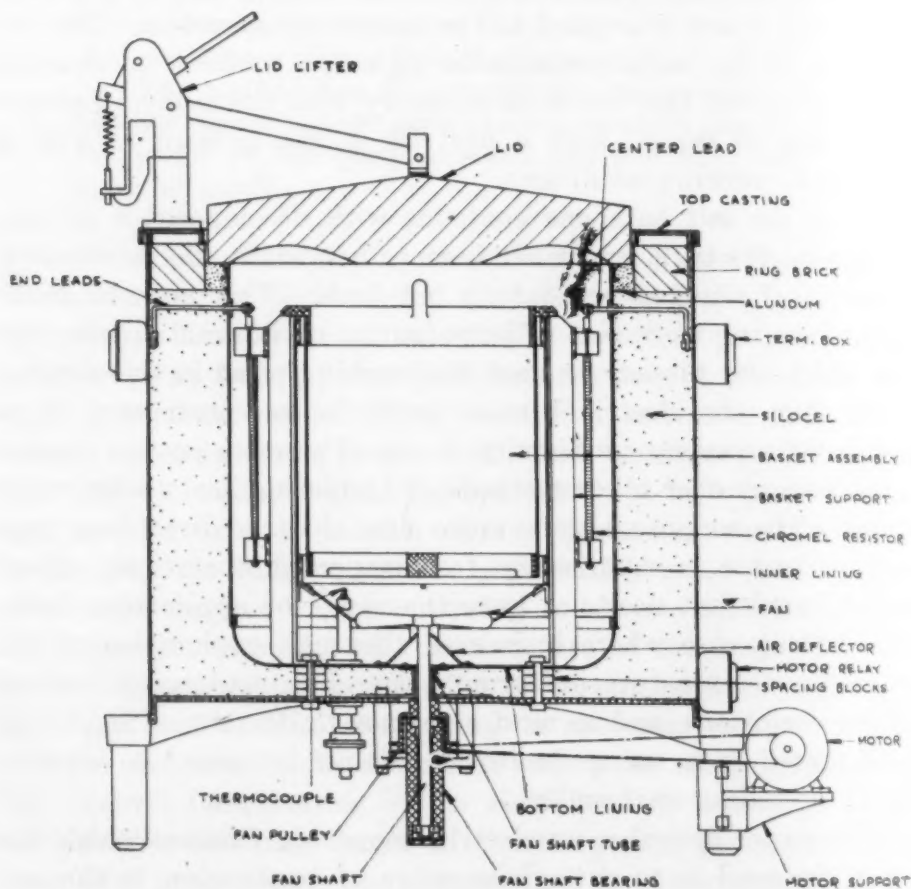


Fig. 1—Cross Section of a Forced Convection Type of Tempering Furnace.

assembly," is the work container. This is open at the top and the bottom consists of a spider covered with coarse wire mesh which permits circulation of air through it when loaded with work. Below this basket is situated the fan, driven by an external motor capable of automatic periodic reversal. The walls of the basket, as well as the wall of the basket support, are of solid sheet metal which, together with circulation of the air, keeps radiation down

to a minimum as far as the load is concerned. The heating element, composed of coils of nickel-chromium wire, is fastened by insulators to the wall of the basket support. The heat capacity of the furnace is kept low in order to provide a system which is sensitive to control without appreciable time lag.

The air circulates through the basket around the heaters and past the fan which is of such a type to work practically equally well in either direction. The thermocouple is placed just below the work container and gives sensitive control, since it responds to small changes of air temperature sooner than does the load. In this way the air temperature is controlled in preference to work temperature and thus all possibility of overheating of the work is eliminated. The remainder of the furnace structure pertains chiefly to insulation, etc., and does not need description here.

The control of the furnace is maintained with a potentiometer type controller recorder. As this type of instrument is familiar to most of the members of this Society it will not be described here other than to point out that it is equipped with a front-setting device for setting temperature at which the tempering is to be done and also with an automatic switch for the periodic reversal of the fan motor. The controller automatically changes the power input into the furnace from high rate required for bringing up the load to a smaller rate sufficient to hold furnace at any desired temperature within its range. The point, at which this change-over is made, is variable with relation to the temperature at which the controller is set to operate, so that the change can be accomplished at any desired distance below the control point. This feature is effective as a further guard against any possibility of over-shooting the control temperature.

In testing the furnace the general procedure has been to place thermocouples uniformly distributed throughout the load so attached to the work as to measure accurately the work temperature. The thermocouples used have been made from the same length of wire and checked for comparative indications at the same temperature. In this way accurate comparative results can be obtained. The records of uniformity have been made with a multiple point potentiometer type recorder. This recorder records consecutively the electromotive force of the several couples, distributed through the load, on the same chart. In the charts to be shown, the numbers and points indicate the readings of the

various thermocouples, each number corresponding to a different couple. Such an instrument as this is adaptable to uniformity tests and is easily manipulated.

As a basis of comparison of the results obtained with a convection type tempering furnace the results of tests with a direct-heat type furnace are used. These results have been obtained with a standard tempering furnace, one which represents good design of this type, inasmuch as the heat is uniformly distributed in the

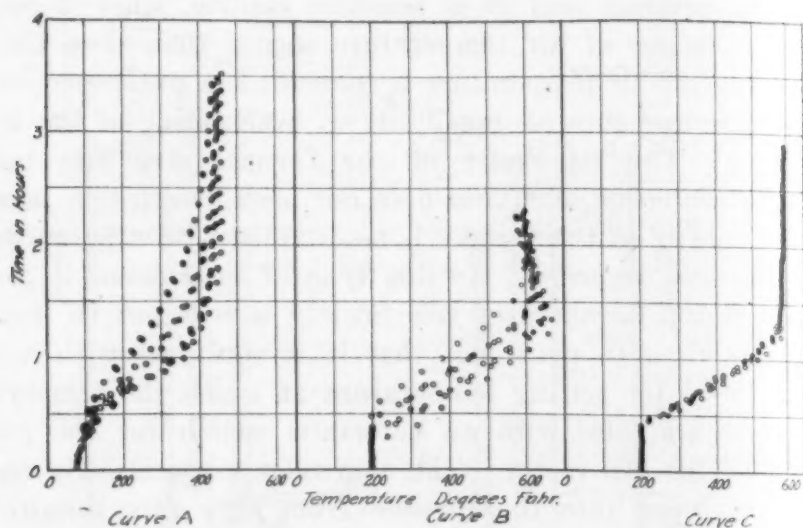


Fig. 2—Reproductions of Heating Curves Showing the Uniformity Obtained in a Direct-Heat Type Electric Furnace.

furnace wall as well as over the bottom of the furnace, thus providing a uniform transfer of heat to the load. These curves are shown to point out clearly the limitations of electric furnaces of the direct-heat type with a view of outlining their field of usefulness rather than condemning their use entirely.

Fig. 2 is a reproduction of the three charts showing the uniformity obtained in a direct-heat type electric furnace loaded with 200 pounds of automobile transmission gears (chart A), compared to that obtained in the convection furnace, without reversal and with reversal of air circulation, when loaded with 700 pounds of gears (charts B and C respectively). The gears in each test were loosely piled in the furnaces. While these tests are not directly comparable, they serve to give a fair idea of the relative performance to be expected. Due to the difference in the paper speeds at which these records were originally taken, they have

been replotted to the same scale and the replotted curves are shown in Fig. 2. From this figure, curve A, it will be noticed that  $3\frac{1}{2}$  hours were required to heat 200 pounds of gears in the direct-heat type furnace to 450 degrees Fahr., at the end of which time the uniformity was within total range of 25 degrees. It will also be noted from this curve that there was a wide difference in the time element of parts on the outside of the load compared with those on the inside of the load. In curve B, which represents the performance of the convection furnace in which the air circulation was not reversed, the time required to heat 700 pounds of gears to 600 degrees Fahr. was much less with approximately the same result as to the uniformity finally reached. There was some overshooting of the control point in this case which could have been eliminated by a slightly slower heating rate as the load approached the control point. Curve C shows the performance of the convection type furnace with periodic reversal of the direction of air circulation, the load being again 700 pounds of gears. Here the heating time was materially decreased as well as the uniformity greatly increased. In this curve it will be noted that all of the work reached the control temperature at almost the same time and that practically perfect uniformity of temperature throughout the load was obtained. The effect of the periodic reversal of air is plainly shown by comparison of curves B and C.

Fig. 3 is a reproduction of charts obtained on identical loads in the direct-heat type furnace and a convection type furnace. In this case the load was composed of 150 pounds of wire nails Nos. 6, 8 and 10. This type of load was chosen in order to have a load which would pack closely and give considerable resistance to air circulation, and thus set up severe test conditions. This type of loading also duplicated fairly closely the conditions to be obtained when such a furnace would be loaded with small tools, such as drills, taps, etc. Curve A in Fig. 3 shows the performance of the direct-heat furnace. The spread of temperature through the load during heating was large, due to low heat conductivity through the load and, although the rate of heating was such that two hours and 40 minutes were required to reach the best uniformity, there was still considerable overshooting of the control temperature. The uniformity reached after two hours and 40 minutes was  $\pm 15$  degrees Fahr. or a total

of 30 degrees Fahr. Curve B of Fig. 3 shows the performance of the convection furnace on the same load. Here the load was

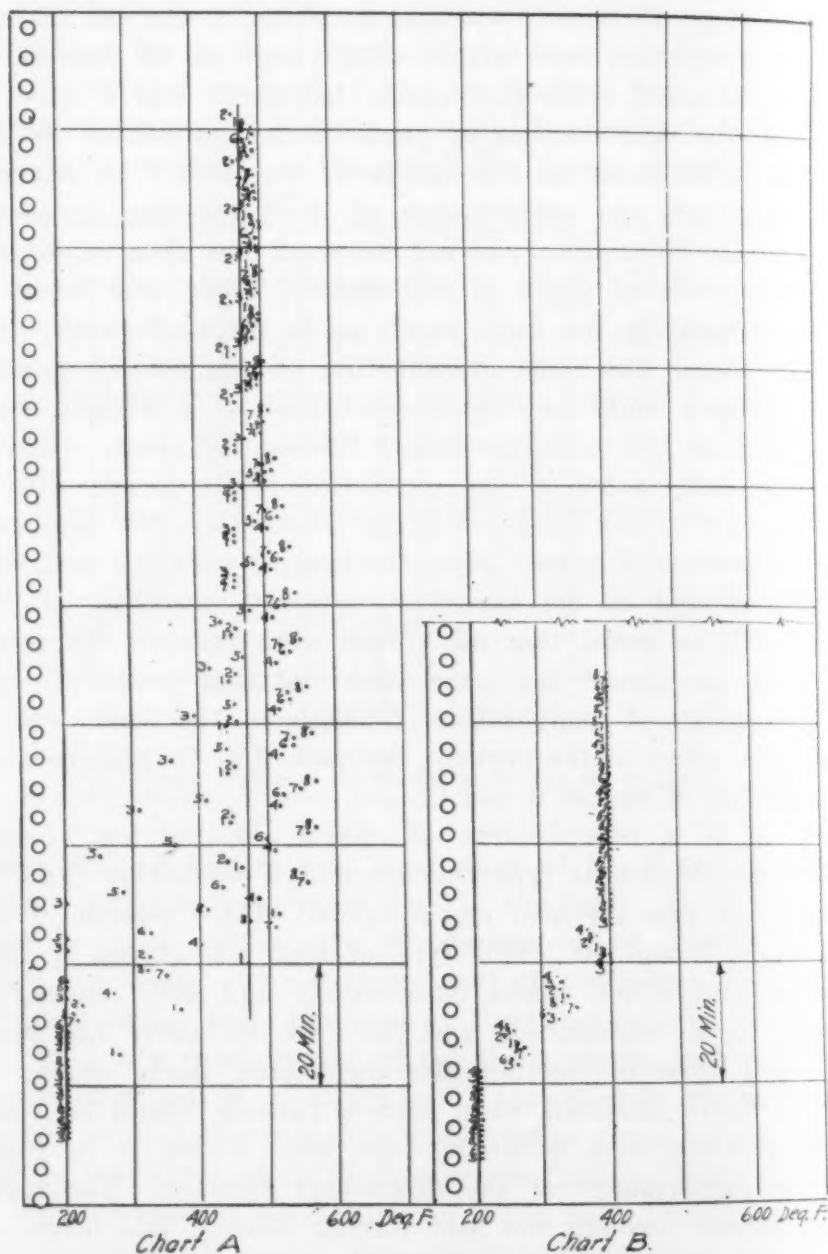


Fig. 3—Reproductions of Curves Obtained on Identical Loads in a Direct-Heat Type of Furnace and a Convection Type Furnace.

heated at a much faster rate with small differences of temperature throughout the load and entire elimination of overshooting

at the control point. The uniformity obtained on control was easily within  $\pm 5$  degrees Fahr. The thermocouples in both of the above tests were made by welding the small thermocouple wires to opposite ends of a nail, thus including the nail itself in the thermocouple circuit, which proved to be a satisfactory method of obtaining temperatures of small work.

In connection with the tests on small work, where consider-

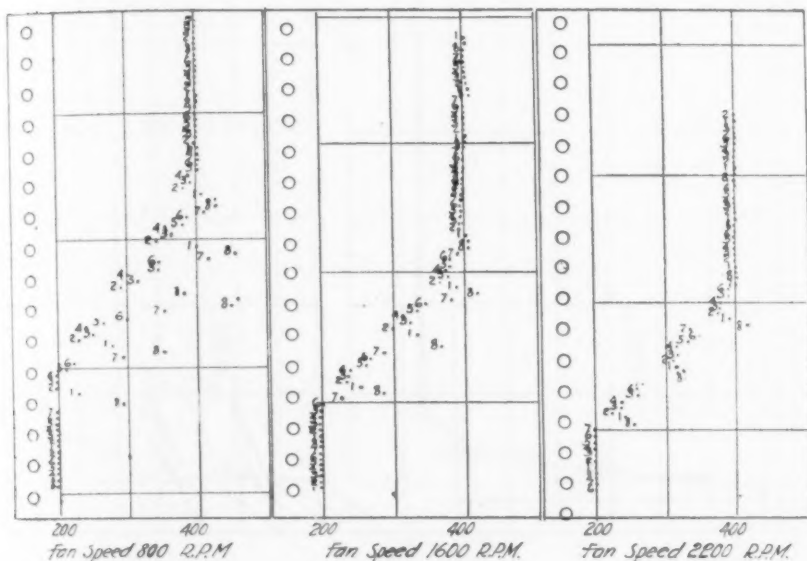


Fig. 4—Group of Heating Curves Obtained at Fan Speeds of 800, 1600 and 2200 Revolutions per Minute.

able resistance to air circulation was developed, it was found necessary to increase the fan speed in the convection type furnace and thus increase the air flow. Fig. 4 shows a group of three curves obtained at fan speeds of 800, 1600 and 2200 r.p.m. These charts show quite clearly to what extent uniformity in this type of furnace is dependent upon the rate of air flow. While the differences in temperature developed during heating with a fan speed of 800 r.p.m. amounted to 180 degrees Fahr., this was reduced to about 40 degrees Fahr. at 2200 r.p.m. It will also be noted that the time of heating to the control point was also reduced at the higher fan speeds.

Fig. 5 shows the uniformity obtained with a convection furnace through a load of 5000 No. 8 machine screw taps on actual production work. The control curve is also shown in this chart.

The multiple-point record in Fig. 5 shows that 20 minutes were required to bring the load to the control temperature with excellent uniformity during heating as well as on control. The variation of temperature with the furnace on control was within

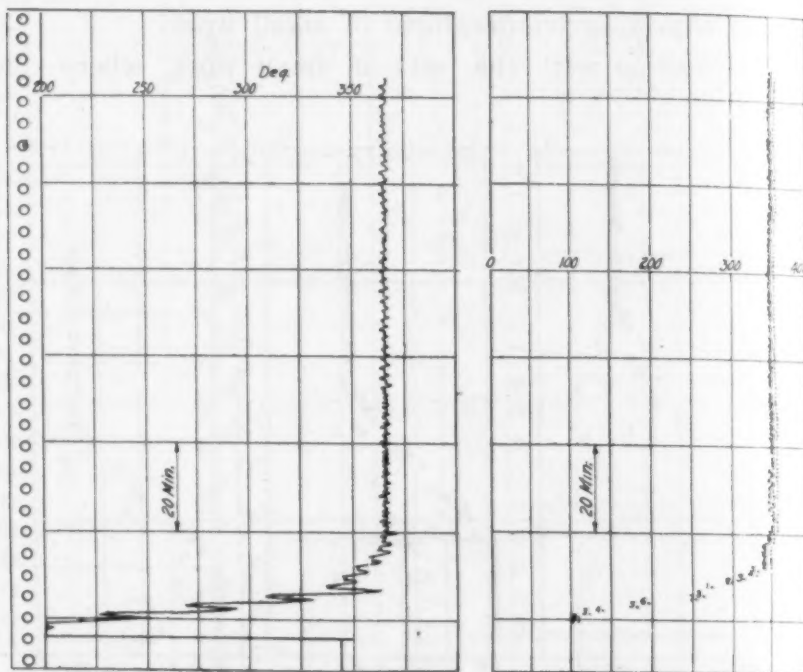


Fig. 5—Curves Showing the Uniformity Obtained with a Convection Furnace Through a Load of 5000 No. 8 Machine Screw Taps.

a few degrees Fahr., while the uniformity was almost perfect.

Referring to the control record, it may be noted how the reversal of air affects the curve drawn by the recorder, there being a reversal of the curve at each reversal of the fan. This feature practically eliminates the controller wave usually encountered, since each cycle serves to expose the control thermocouple to the hottest air as well as the coolest air in the furnace. The variation of air temperature is approximately  $\pm 3$  degrees Fahr. In comparing the two curves it will be noted that the work temperature is 5 degrees Fahr. below the control temperature. This difference is controlled by the distance of the control thermocouple from the work. It may be decreased by placing the thermocouple nearer the work and eliminated where the thermocouple is in contact with the work. However, the sensitivity of control gained by placing the control couple at a small dis-

tance from the work is probably of more value than the true indication of work temperature, since this small difference can be compensated for in setting the control temperature.

Furnaces of this type have been applied to a number of different kinds of work and are showing satisfactory performance with a low cost of operation.

## INDUSTRIAL HEATING

BY H. F. SMITH

### *Abstract*

*This paper discusses industrial heating from the viewpoint of the engineer. The selection of fuel or heat source, the liberation of this heat in proper manner and the transfer of this heat to the work is discussed in detail.*

*Various sources of heat are discussed and their advantages and disadvantages given.*

*The problems of handling the various types of fuels and their conversion into heat units are outlined.*

*Details of furnace design are also covered.*

**T**HE problems involved in industrial heating as they present themselves to the engineer and to those in responsible charge of industries may be naturally divided into three parts.

First: The selection of a source of heat, that is to say, fuel

Second: The liberation of this heat in proper manner at the point where it is required, that is to say, the problem of combustion

Third: The transfer of this heat to the work, or, in other words, problems relating to industrial furnace design.

These problems are all much involved and much inter-related, but a separate treatment along the lines indicated serves to reduce to some extent the natural confusion.

The original source of all heat is, of course, the sun. No method is available for the practical direct utilization of the sun's energy. Two indirect methods are available. First, the utilization of water power, which takes advantage of a portion of the sun's energy which falls upon the ocean and other large bodies of water, and second, the use of vegetable matter as fuel, which makes use of chemically bound energy of a portion of the sun's heat which

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A paper presented before the Cincinnati Chapter of the Society. The author, H. F. Smith, is consulting engineer of the Smith Gas Engineering Company, Dayton, Ohio.

falls upon productive land surfaces. Water power can be made available for heating only through the agency of electricity.

Fuels are divided roughly into two classes. First, vegetable fuels, under which head may be included those things which are produced from year to year, such as wood and vegetable waste from various farm products. These are renewed from year to year and constitute an inexhaustible source of energy. The available amount is, however, limited. Second, mineral fuels, which include natural gas, oil and coal. These represent the stored energy of the sun and are available in enormous quantities whenever we choose to take them. The supply, however, is distinctly limited, is not being renewed and is, consequently, becoming depleted. As mineral sources of fuel become depleted greater attention must be given to the utilization of the constantly renewed vegetable products. Of these, perhaps, the largest amount is waste from lumbering operations. Of the total growth of a tree usually not more than half becomes merchantable lumber, the balance being waste. Modern methods of lumbering, as illustrated by the latest plant of the Ford Motor Company at Iron Mountain, Michigan, makes possible the utilization of a great deal of this waste, which becomes the source of valuable high grade chemical products and small sized wood charcoal. This latter material is a desirable source of industrial gas for those operations which require gas of extraordinary purity and low sulphur content. It will also form a desirable source of domestic fuel. The total quantity of this sort of fuel available from sawmill waste is much larger than is commonly supposed.

Of the mineral fuels, natural gas is rapidly disappearing as an industrial fuel. It is ideal in its properties and is one of the few natural products which has been marketed at a price far below its true competitive value. Oil has been and is still an important factor in industrial heating, but this, also, has been produced at a price little, if any above, the actual cost of getting it out of the ground. It has been frequently stated by those who should know that the cost of oil wells drilled is greater than the selling price of all crude taken from the ground. This condition is a result of the highly speculative character of oil production. No one can predict the future of the oil situation, except that oil is certain to become increasingly scarce and increasingly high in price. A large part of the present oil production goes into transportation.

The highest value products are used by the automobile industry. Oil of less high grade is being used in increasing amount by Diesel engines for ship propulsion. It is easily possible to imagine that this method of power development may soon become practical for railway use. Cracking processes make it possible to convert a large percentage of the total crude oil into gasoline or Diesel engine fuel. There is always, of course, a residue of heavy low grade oil which will be available for fuel purposes, but this finds a ready market as bunker oil for oil-fired steamships, and will, no doubt, find an increasing market at high prices in the future as domestic fuel. The outlook for a supply of cheap fuel oil for industrial purposes is decidedly not encouraging. On the other hand, there is no reason to anticipate an oil shortage or an oil failure for those uses outlined above which can afford to pay a high price for fuel.

Coal has always been recognized as the basic fuel of industry. It will, no doubt, occupy an increasingly important position as time goes on. The problems involved in production and utilization of coal are many. Significant progress has been made recently in reducing the ash and sulphur content of coal, the Chance Sand Flotation Process for separating high ash from low ash fuel, and the Trent Oil Amalgamation Process, by which similar results are obtainable, are the two most outstanding developments. By the use of these processes it is possible to take high ash high sulphur coal and economically produce from it low ash low sulphur coal.

A second step in the preliminary treatment of coal is the coking process. The high temperature coking processes are well known and established. Low temperature coking is gaining ground, but seems to depend for its commercial success on the relative cost of liquid hydrocarbon products, of which crude oil is now our chief course of supply. With increasing cost of crude oil low temperature carbonization will find increasing utility.

After the matter of preliminary preparation comes the question of transporting coal from the mine to the place of use. Three methods are suggested.

First: Conversion into electricity at the mine and electric transmission to point of use

Second: Gasification of the coal at the mine either in whole or part and transmission of gas to the point of use.

**Third:** The customary and more widely used method of shipping the coal either in its initial state or in partially prepared form from the mine to the point of use.

It should not be too readily assumed that the first two methods mentioned transport heat at low cost. Figures given in the Giant Power Survey for the state of Pennsylvania indicate that transmitting heat by way of electricity from the mine to a point of, say 300 miles distant, would cost the equivalent of approximately \$15.00 per ton freight charge in coal. Transmitting heat in the form of gas over the same distance reduces the carrying charge to approximately \$5.00 per ton of coal. Neither of these processes compare favorably with current freight rates on coal.

In the case of the use of coal delivered by freight to the consumer's premises, however, further preparation of the coal is usually required after delivery. It is, of course, possible to use coal as delivered in direct fired furnaces, but this method is increasingly unpopular. The coal may be pulverized and burned in this form with results that are distinctly superior to direct firing. The use of pulverized coal, however, has limitations in that all of the ash contained in the coal is carried into the furnace and also large combustion chambers are required for the satisfactory burning of coal in this form. These two limitations are of no consequence in some applications, but are vital in others. Coal can be converted into gas whereby all of the ash and many chemical impurities are left behind, and distributed and burned in this form in a satisfactory manner. The gasification of coal can be carried out either as a public service operation and the gas distributed to the industrial user through city delivery system, or the industrial user can operate his own gas plant. High distribution costs and political restrictions that surround public service corporations frequently make privately owned gas plants highly profitable. Gas, whether from public service supply or manufactured on the premises is, perhaps, the most flexible of all industrial fuels. Electricity has lately appeared as a competitor of gas for industrial heating operations, but is essentially a costly heating medium. Heat in the form of electricity at 1 cent per kilowatt hour is about the same in cost, B.t.u. for B.t.u., as good grade bituminous coal at \$80.00 per ton. This is a high price for fuel,

and can be tolerated only in view of the fact that most industrial furnaces using coal or gas are notoriously inefficient. This inefficiency is not by any means inherent or necessary, but is only the result of carelessness on the part of those who design, build and use industrial furnaces. There are few industrial operations which can be done electrically that cannot be done equally well at materially lower cost with gas.

The final selection of a suitable source of fuel for an industrial plant depends entirely on local conditions and is not subject to general analysis. It may be said, however, in general, that it is better to have a centralized fuel supply source and to use one sort of fuel universally throughout the plant than to have three or four different types of apparatus and three or four different sorts of fuel service supply.

After having decided on the type of fuel best adapted, the next question to receive consideration is the proper liberation of the heat in the fuel. In the case of electricity this consists in proper selection of the type of resistance units employed. In the case of gas the problem is one of providing proper facilities for combustion, proper facilities for control of air and gas supply, and proper facilities for recovery and use of waste heat. The same conditions apply to the use of pulverized coal with the exception that for powdered coal installations the recovery and utilization of waste heat is considerably complicated by the presence of ash in the flue gas and by the inherent high flame temperature of powdered coal.

Two principal sources of loss from combustion furnaces are radiation through the walls of the furnace and loss from high temperature gases passing to the stack. Both of these losses are avoided by the use of proper furnace design and construction. It is not necessary to comment on the fact that properly built and economical gas furnaces cost more to install than improperly built and uneconomical furnaces. However, this additional expense will usually pay handsome returns on the investment except in those rare instances where fuel is extraordinarily cheap.

The subject of heat recuperation on industrial furnaces is one which should receive most careful consideration. It is at this point alone where a gas furnace is of necessity decidedly at a disadvantage compared with an electric furnace. The electric furnace inherently does not discharge hot gas outside the furnace structure.

The gas furnace must do so. It is entirely possible to recover a large percentage of the heat lost in stack gases from combustion furnaces by methods that are at present well developed and available. We may now consider briefly the transfer of the generated heat to the work.

It has been in the past quite common in industrial furnaces to combine to a considerable extent the combustion chambers and the heating chambers of the furnace. In some cases this is a justifiable procedure. In others it is decidedly out of place. Heat is usually delivered from the combustion chamber of the furnace in the form of high temperature gases. Heat from these gases can be transferred to the work by two methods. First, by direct contact, and second, by radiation either from the hot gas itself or by some solid in contact with the gases and which is in radiating relationship with the material to be heated. In most industrial furnaces this latter feature is by far the larger one involved in the heat transfer. The walls of the furnace absorb heat by contact with the hot gases passing through. The surface of these walls is usually large compared to the surface of the work being heated, and, consequently, the opportunity to absorb heat from the hot gases is greater, and the heat thus absorbed is transferred to the work at enormously high rates, particularly where the working temperature of the furnace is high. Between so-called black bodies the rate of transfer by radiation is proportionate to the fourth power of the absolute temperatures. At low temperatures this radiation rate is not extraordinarily high and is comparable to the convection rate. At high temperatures, however, that is to say, above 1500 degrees Fahr., the rate of transfer by radiation becomes extremely high. It should not be overlooked that while this is a convenient method of heat transfer to the work it is also a fruitful source of heat loss from furnaces if they are provided with open doors or other openings through which the interior of the furnace can establish optical relationship with cooler outside objects. Only an inspection of the actual rates of transfer from a suitable fourth power diagram can convey an adequate sense of the magnitude of this method of transfer and of these sources of heat loss from furnaces. It is a part of the engineer's opportunity in furnace design to convert these methods of heat transfer to his own use and to prevent to as large extent as may be the losses of the various sorts which may

come about through improper knowledge of the methods by which heat is transferred. In the case of electrical furnaces the likelihood of loss through radiation from openings is to be especially guarded against in view of the fact that the entire heat supply to the furnace is from high temperature radiating elements, and to the further fact that the source of heat is costly and losses must accordingly be guarded with special care. This fact is usually much more clearly recognized by electric furnace designers than by builders of combustion furnaces.

The desirability of separating the combustion space from the work space in combustion furnaces should be carefully considered, especially for smaller furnaces where refinement of heat control and the question of the particular type of furnace atmosphere desired are of importance. Materials are now available which permit this sort of segregation in gas furnaces with highly satisfactory results. In gas furnace design the matter of automatic control of temperature should also receive careful attention. These things are accepted as a matter of course with electric furnaces, but are usually overlooked in furnaces designed for less expensive fuels. The point should be emphasized, however, that by proper design it is possible to secure with a combustion furnace, temperature control, uniformity of operation and regulation of atmosphere surrounding work, which will equal for most operations anything that can be attained by the most highly refined type of electric furnace. The cost of such a furnace may approximate the cost of the equivalent electric furnace, but the operating expense will be found to be invariably much lower, and the results at least equal, and in some cases superior.

## Educational Section

These Articles Have Been Selected Primarily For Their Educational And Informational Character As Distinguished From Reports Of Investigations And Research

### THE MANUFACTURE OF IRON AND STEEL—PART II<sup>1</sup>

By F. T. Sisco

#### *Abstract*

*In the present installment the author discusses the mechanical treatment of steel, including hot and cold working.*

*The effects that mechanical working have upon the steel are discussed, and the equipment and methods of handling the steel in the mill are dealt with.*

*In a future installment the author will cover the methods of producing iron and steel castings.*

#### THE MECHANICAL TREATMENT OF STEEL

PRACTICALLY all of the steel tonnage in the United States is produced in the molten state by melting and refining pig iron, scrap, or a mixture of the two. Using this molten metal, the finished steel product may be made by one of two general methods: (1) pouring the metal into a large block or ingot and producing the finished section by mechanical pressure; or (2) pouring into a mold which is the shape of the finished piece. The former is known as mechanical treatment and is subdivided into hot working and cold working. The latter is known as casting or founding.

Three factors govern the choice of processes: (1) shape, size, and quantity of the finished sections; (2) the cost; and (3) the quality desired.

Some finished sections are so intricate that they must be

<sup>1</sup>This is the second installment of a series of articles on the Metallurgy of Iron and Steel being prepared for the Officers' Engineering School, Air Service, and is published by permission of Chief of Air Service by authority of Lieut. E. E. Aldrin, Chief of School Section, McCook Field, Dayton, Ohio.

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produced by casting; to work them into shape by mechanical treatment could only be done at an exorbitant cost and usually only by the aid of excessive machining. On the other hand, if the finished piece must be strong and ductile and the shape is not too complicated, this strength and ductility may be imparted by mechanical treatment. Between these two extremes are infinite graduations. The choice of the process for finishing steel naturally involves a consideration of the three factors noted above.

In the present installment the mechanical treatment of steel will be discussed; in a following installment the method of producing iron and steel castings will be described in some detail. In general, mechanical treatment is used only for steel (and for wrought iron, which may be classed as steel in this discussion). Casting is used for both iron and steel.

#### HOT WORKING AND COLD WORKING

Hot working is mechanical treatment applied to steel when the metal is at a high temperature. Cold working is mechanical treatment when the metal is at a low temperature. There is no sharp dividing line between the two; in general, hot working refers to mechanical treatment of the metal when it is hot enough to display a visible color, that is, 1200 degrees Fahr. (650 degrees Cent.) or above, and cold working refers to working below this temperature. Usually cold working refers to mechanical treatment when the metal is at or near atmospheric temperature. We might say that hot working is work applied to the metal when it is more or less plastic; and cold working when it is not plastic.

It is desirable that we spend a few moments discussing the two words, "hot" and "cold." These two words are used more frequently in the steel mill than any others and usually with a meaning somewhat different from the usual one. As used in the mill, hot and cold are relative only and refer to a deviation from a fixed temperature. An example will make this clear. The open hearth melter, in noting the condition of his steel while tapping, decides that the "heat is too hot" or "too cold." If, in his experience, he has found that a temperature of about 2900 degrees Fahr. (1600 degrees Cent.) is the best for the steel in question, and has a tapping temperature of 2800 degrees Fahr., he

has tapped a "cold heat." If the steel is about 3000 degrees Fahr. he has tapped a "hot heat."

The roller, in noting the temperature of the steel as it comes from the heating furnaces, decides that it is too hot or too cold, depending on whether it is above or below the normal rolling temperature for that particular steel. In the same way a rolled section may be finished too hot or too cold. These examples are typical of the mill use of the words, "hot" and "cold"; they simply signify a deviation from the normal temperature.

### HOT WORKING

Hot working increases the strength of steel 200 to 300 per cent, sometimes more. This is due to the breaking up of the large coarse crystalline masses in the ingot and increasing the cohesion and adhesion of the various crystalline units. Very large crystals such as are found in ingots are weak and brittle because the cohesion and adhesion of the crystals for each other and of the various units in the crystal for each other is small. Another advantage of hot working is that the pressure serves to close up gas cavities and blowholes and to elongate solid non-metallic inclusions into threads or fibers. It also serves to elongate the crystals themselves in the direction of working.

There are two general diversions of hot working: (1) forging; and (2) rolling. The former is usually more costly but is specially adapted to rather complicated sections. The latter is used in the forming of simple sections produced in large tonnages. The application of pressure may be controlled more closely in forging than in rolling. A forged section is considered to be of higher quality than if rolled.

### *Forging*

Forging may be accomplished in two ways: (1) by the sudden and instantaneous application of pressure as in hammering; or (2) by the steady application of pressure as in pressing. The latter method is usually spoken of as forging to distinguish it from hammering.

Unless the section is small the effect of hammering is superficial, as it affects only the surface of the piece. Hammering is

slower than pressing, but if the effect of the work goes to the center the best possible structure results. The greatest advantage of hammering is that the operator exercises an absolute control

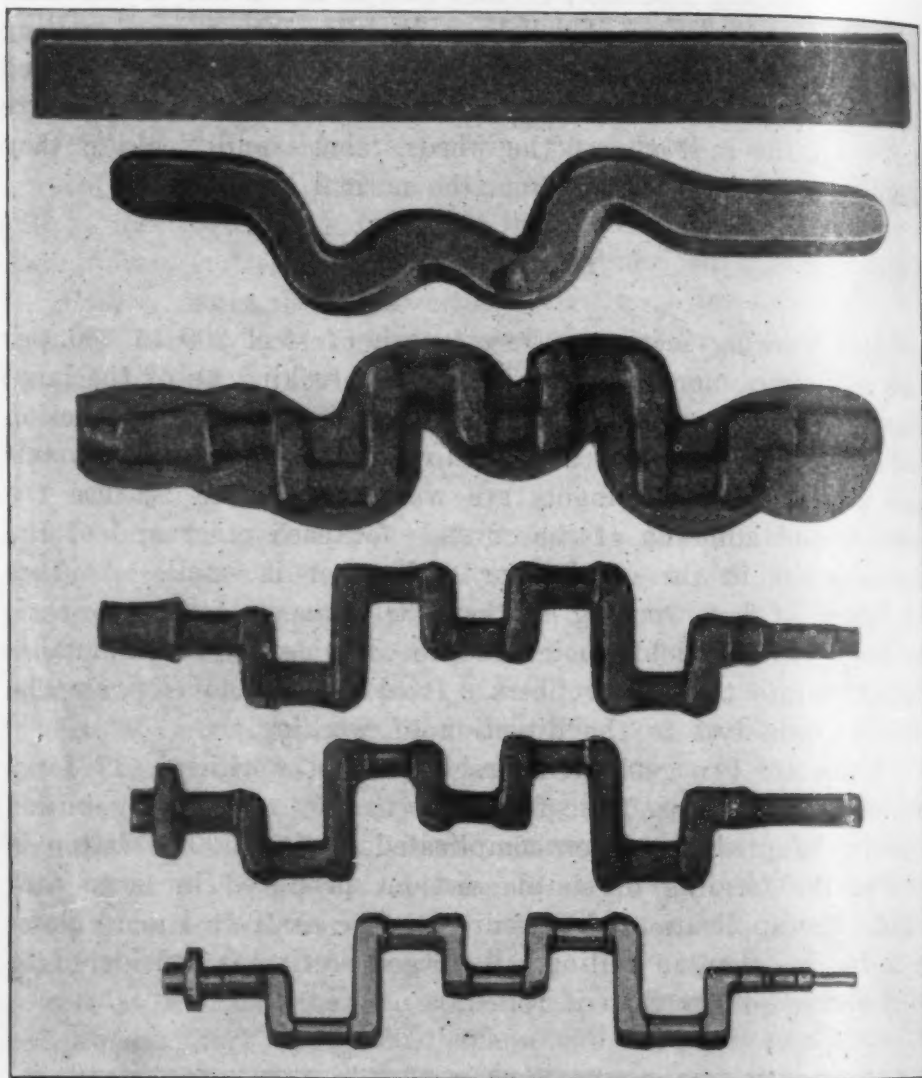


Fig. 1—Stages in Making a Drop Forged Crankshaft. (Bradley Stoughton.)

over the amount of pressure applied and over the finishing temperature and is thus able to produce the most desirable structural characteristics and resulting physical properties in the piece.

A modification of hammering is drop forging. This process is especially adapted to the production of fairly intricate sections in large quantities. The steel is forged between two dies, one

of which is attached to the head of the hammer and the other to the anvil. Fig. 1 shows the various stages in making a drop

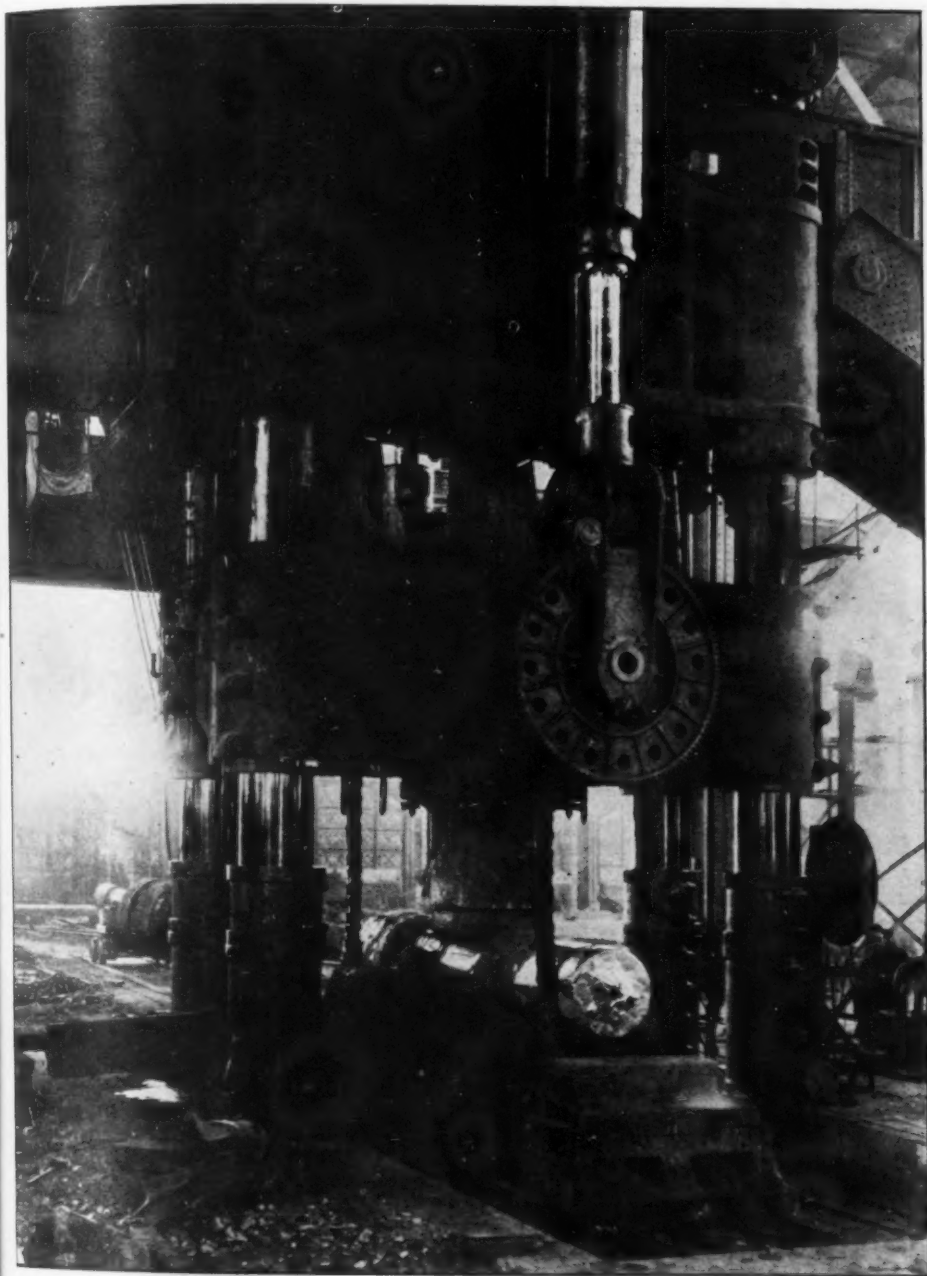


Fig. 2—A 14,000-ton Hydraulic Forge Press.

forged crankshaft from a flat bar.

Tools, gears, shafts, various automotive parts, such as steer-

ing knuckles, crankshafts, connecting rods, and the like, are drop forged.

When the finished parts are of large and heavy sections hammering can no longer be used. It is then necessary to forge the piece in a hydraulic forging press. Fig. 2 shows a 14,000-ton armor plate press. This press, the largest in existence, is used

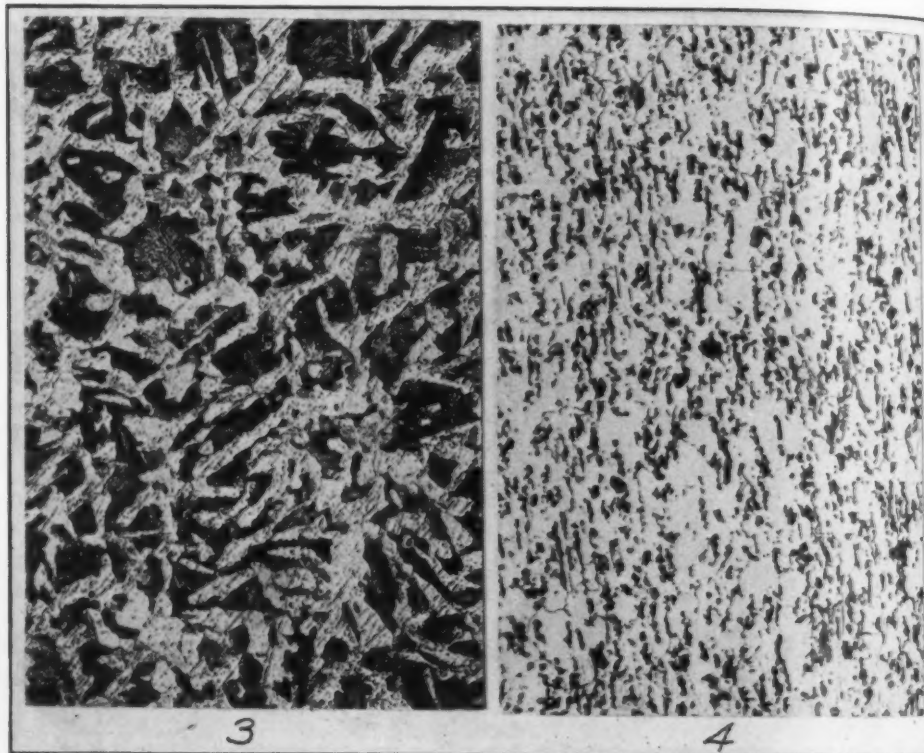


Fig. 3—Photomicrograph of a Polished and Etched Specimen of Steel Containing 0.33 Per Cent Carbon, as Cast. Magnification 100x.

Fig. 4—Photomicrograph of a Polished and Etched Specimen of Steel Hot-Worked, Containing 0.35 Per Cent Carbon. Magnification 100x.

for armor plate, large caliber guns, and other heavy sections. Forging presses range from this size down to 600 tons capacity.

Pressing has the advantage over hammering in that the work affects the whole cross section of the piece instead of just the surface.

The effects of hot working on the grain size of steel are shown in Figs. 3 and 4.

#### *Finishing Temperature*

The temperature of the piece when hot working processes are completed is a most important variable in its relation to

grain size and quality. As will be discussed later, all steels have a thermal transformation or critical range, in which they undergo certain structural changes. Above this range, which varies from 1360 degrees Fahr. (740 degrees Cent.) to about 1600 degrees Fahr. (870 degrees Cent.), the crystalline masses tend to grow in size. If the finishing temperature of the metal is too high crystal growth will partially or wholly counteract the breaking up of the grains in hot working and the piece will be of inferior quality. If the finishing temperature is below the critical range the metal is hardened.

The operator of the forging press, hammer, or rolling mill attempts to heat his metal for hot working so that the temperature when the work is finished will be just slightly above the critical range.

### HOT ROLLING

More than 80 per cent of all hot worked steel products are hot rolled. Mills have been developed mechanically until they have reached a high state of perfection; producing a high grade product, in great tonnage, and at a low cost.

There are three main divisions to the process of hot rolling: (1) heating; (2) roughing; and (3) finishing. The first includes preparing the ingots for the roughing mills and reheating the partly rolled sections for the finishing mills. Roughing includes breaking the ingot down into the sizes and shapes necessary for the various finishing mills, and finishing is what the name implies, rolling the finished section.

A finished steel product may be a shape, which is used as rolled, or it may be a bar which is to be subjected to further work, such as machining.

### *Heating for Rolling*

Ingots to be rolled are reheated in soaking pits; semi-finished sections are reheated in heating furnaces.

The soaking pit is a regenerative furnace constructed as a vertical covered pit, usually fired by coke-oven, or producer gas, in which 4 to 8 ingots may be placed. Fig. 5 shows the method of charging the ingot. When the ingots are stripped, generally  $\frac{3}{4}$  to 1 hour after teeming, they are relatively cold, a dark red

on the surface, and still molten in the center. In the soaking pit, which is maintained at a temperature of 2000 to 2400 degrees Fahr. (1100 to 1320 degrees Cent.), the heat is equalized throughout the body of the ingot and the whole mass brought to the rolling temperature. It is necessary to soak the ingot for

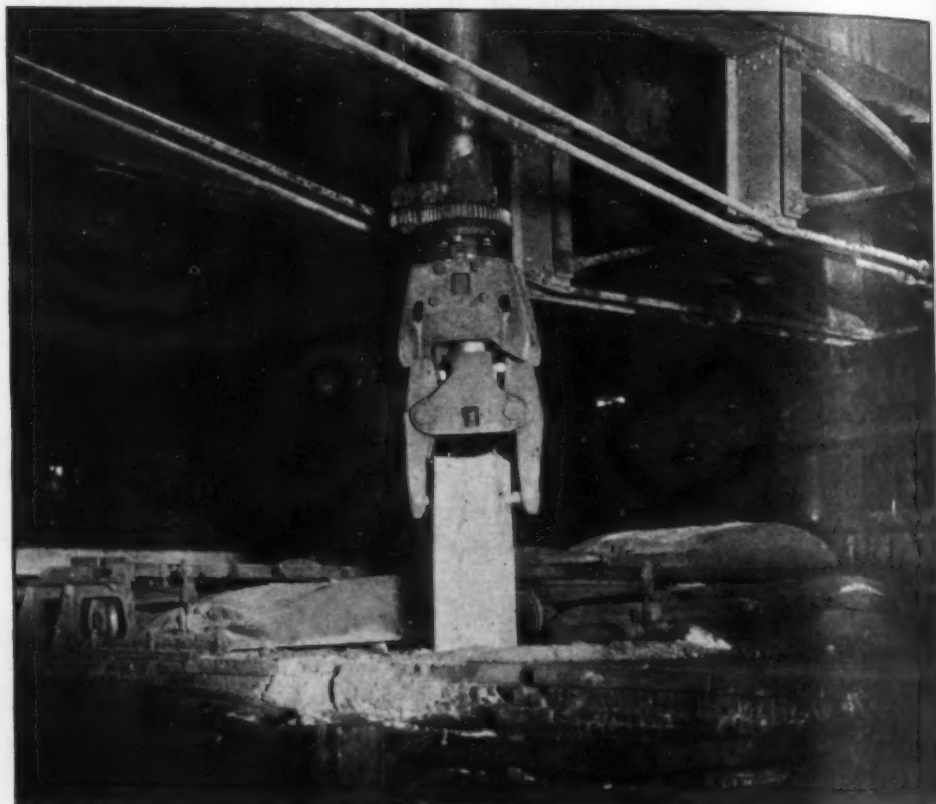


Fig. 5—Charging the Ingot into the Soaking Pit.

approximately the same length of time the metal was in the molds before stripping. This is 45 minutes to an hour.

Heating furnaces have a horizontal hearth and may be fired by coal, oil, or gas. Most recent installations are recuperative. For fairly large blooms and slabs 9 by 9 inches and larger, charging machines are used to place the piece on the hearth or remove it from the furnace. For smaller sections, such as billets 6 by 6 inches and smaller, and occasionally for the larger sizes, the furnaces are continuous, the cold steel is charged at one end and is pushed slowly through the furnace. The pieces heated

to rolling temperature, drop out of the other end of the furnace onto the conveyor, which takes them to the mill.

#### CLASSIFICATION OF ROLLED PRODUCTS

Rolled products are classified according to their shape and size and according to the section into which they are to be finished. The names applied to semi-finished rolled products are blooms, billets, and slabs. A bloom is a section of steel approximately square, 6 by 6 inches in size or larger. When the section is approximately square and is less than 6 by 6 inches it is called a billet. Slabs are rectangular sections in which the width is greater than twice the thickness. Slabs are the intermediate product between the ingot and plates or sheet. If the section is rectangular but with a width less than twice the thickness it is known as a rectangular bloom. In certain high grade steels when the finished product is a round bar, the ingot is rolled to a section intermediate between a round and a square. This section, which may be likened to a square with rounded corners, is known as a Gothic billet.

When a finished steel section is to be used for products requiring machining it is called a bar. Bars may be round, square, hexagon, or octagon. If the width is more than twice the thickness it is known as a "flat." Bars are given one or more final passes through a pair of finishing rolls, which give the surface of the steel a smooth finish. The finishing rolls also serve to bring the bar to exact size. Bars are usually cut square on each end with a "hot saw." Blooms, billets, and slabs and other sections to be reheated and rerolled are sheared.

#### CLASSIFICATION OF ROLLING MILLS

The more common rolling mills are classified in Table I.

The largest proportion of rolled steel products, structural shapes, rails and plates, are rolled into blooms or slabs and reheated to be rolled into the finished section. For rods, bars, and small shapes two reheatings are usually necessary; the material is rolled into blooms and then to billets.

The classification shown in Table I is only approximately correct. There are many deviations possible. For example, some mills roll rails directly from the ingot, although this is not considered the best practice. In like manner, ingots may be roughed

to billets, which are, in turn, rolled to small rods and bars. The classification of rolling mills given in Table I is naturally dependent upon the initial size of the ingot, the size of the finished

**Table I**  
**Classification of Rolling Mills According to Finished Product**

|       | Roughing<br>Mill | Semi-Finishing<br>Mill        | Finishing<br>Mill     |
|-------|------------------|-------------------------------|-----------------------|
| Ingot | None             | None                          | Universal mill plates |
|       | Slab             | None                          | Universal mill plates |
|       | Slab             | None                          | Eye bars              |
|       | Slab             | None                          | Sheared plates        |
|       | Blooming         | None                          | Structural shapes     |
|       | Blooming         | None                          | Rails                 |
|       | Blooming         | None                          | Rail joints           |
|       | Blooming         | Billet                        | Rods                  |
|       | Blooming         | Billet                        | Small shapes          |
|       | Blooming         | Billet                        | Bars                  |
|       | Blooming         | Billet                        | Hoop                  |
|       | Blooming         | Billet                        | Seamless tube         |
|       | Blooming         | Sheet bar                     | Sheet                 |
|       | Blooming         | Skelp                         | Tube, pipe            |
|       | Blooming         | Billet (Forging billets) none |                       |
|       | Blooming         | Bar (Forging bars) none       |                       |
|       | None             | Bar (Bars from small ingots)  |                       |

section, and the grade of steel. This latter variable determines the amount of draft which may be used in reducing the metal to its final shape and size.

#### THE ACTION OF ROLLING MILLS

The process of reducing the cross-section of a piece of steel by rolling is shown in Fig. 6. The action of the mill is both of tension and compression. The outer layer of the piece is in tension tending to tear itself apart, while the inner layers are in compression. The kneading action of rolling is not as uniform as in hammering or pressing; as the piece is reduced in cross-section it becomes elongated along its major axis only. An exception to this is in plates and sheet where elongation is along the major axis and parallel to it. In hammering and pressing the metal is subjected to compression more than to tension, the kneading action is more thorough, and thus a better structure results.

Another factor entering into the possible inferiority of rolled steel compared to the forged or hammered product is that finishing temperatures are nearly always too high. As the temperature at

which steel is worked is raised, the metal becomes more plastic and, consequently, not so much power is needed to roll the material. From this it follows that drafts may be heavier and rolling speeded up considerably. Hence it is always a temptation for the roller to heat the steel a little too hot to save power and increase the tonnage, resulting in a finishing temperature that is

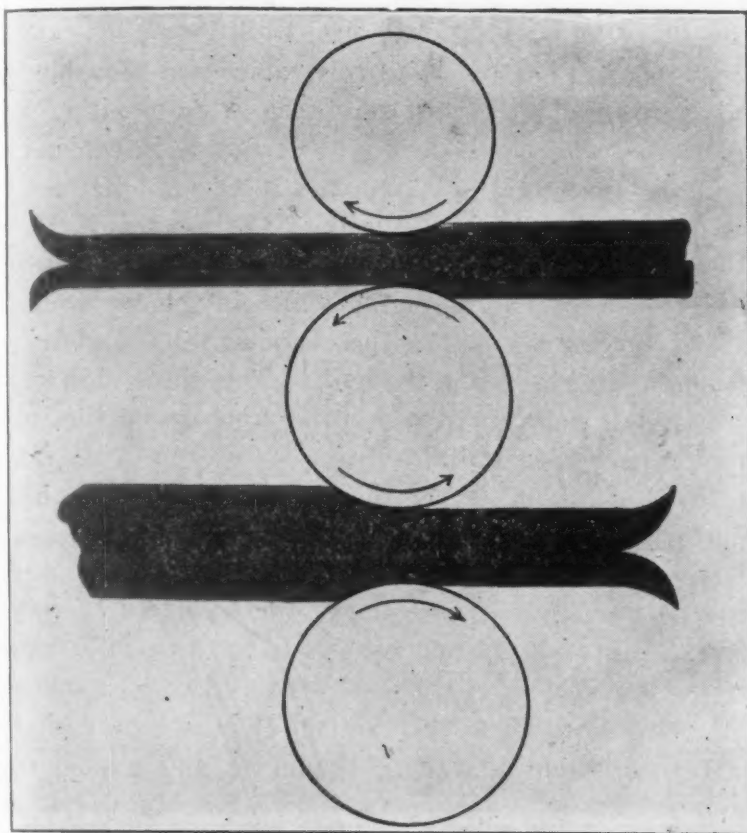


Fig. 6—Diagram Showing the Action of a 3-High Rolling Mill.

too high and a finished product that is inferior to one hammered or pressed.

#### TYPES OF ROLLING MILLS

Rolling mills are classed as two-high and three-high; and reversing and non-reversing or continuous mills. With the exception of a few plate and sheet mills all two-high mills are reversing. Three-high mills are non-reversing or continuous.

In a two-high reversing mill the ingot goes through the mill; the mill and roll tables then stop and reverse. The ingot, which

is tilted 90 degrees, then passes through the mill again. Fig. 7 shows a two-high reversing blooming mill and the method of tilting the ingot for each pass.

In a two-high reversing mill the upper roll is adjustable and is slightly lowered after each pass, thus reducing the size of the opening between the rolls.

In the three-high mill the piece goes through the pass between the lower and middle rolls and back between the upper and middle rolls (see Fig. 6). The roll tables are movable and may be raised or lowered to permit the piece to enter either the upper or lower pass. The three-high mill is not adjustable, hence for sections of different size or shape the rolls must be changed.

The three-high continuous mill is the most efficient mechanically; 60 per cent or more of the power transmitted to the rolls is available for work on the metal, while in the two-high mill less than half of this is available; the rest must be used in overcoming the inertia in reversing the mill. The three-high continuous mill is about 100 per cent faster, producing twice the tonnage of the two-high reversing mill.

The greatest advantage of the two-high reversing mill is that it is adjustable and, hence, more flexible. Various sizes of blooms and billets can be rolled with one pair of rolls. In addition the draft can be changed, if necessary, for steels of different temperatures. The two-high reversing mill is especially adapted to long lengths. Another advantage of the two-high mill is simplicity of roll design. The reversing mill is, however, more costly than the three-high mill, due to the large and expensive engine installation necessary.

A three-high mill installation consists of a sufficient number of stands<sup>1</sup> to roll the bloom to the finished piece with one heating. The stands in a mill installation are known as the roughing (the first stand), the planishing or leader (the intermediate stands), and the finishing stand (the last pass).

### PLATE AND SHEET MILLS

Fig. 8 shows a three-high plate mill. In rolling plates the ingot is reduced to slabs; these are then reheated to approximate-

<sup>1</sup>A stand comprises the rolls, the housings which hold them in place, the various bearings, chocks, etc.

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ly 2375 degrees Fahr. (1300 degrees Cent.) and rolled to finished gage in a mill similar to the one shown in Fig. 7. After rolling, the plates are cold sheared to exact width and length. Mills for rolling sheared plate are nearly always three-high. The upper and lower rolls are the same size; the middle roll is smaller in diameter than the other two. The upper roll is adjustable.

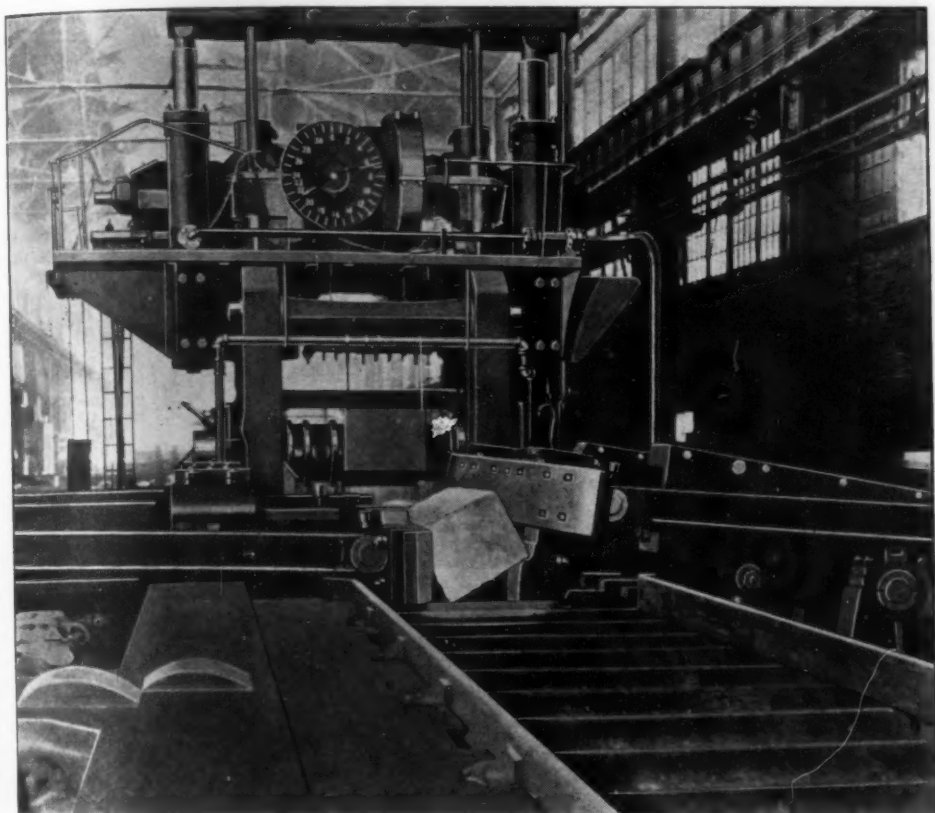


Fig. 7—Photograph of a 2-High Reversing Blooming Mill. Ingot Tilted by Manipulator.

Another form of plate mill is the universal mill. This is a two-high mill but in addition to the main horizontal rolls there are also two vertical rolls. This mill is more complicated and more difficult to operate than the three-high mill but has the advantage that long plates with a smooth rolled edge can be produced, which is not possible with the three-high mill. The universal plate mill also produces a greater tonnage than the other.

Sheet mills are usually non-reversing and may be either three-high or two-high. The roughing stands are generally three-high, while the finishing stands are two-high, pull-over mills.

Sheet mills are nearly always hand mills, that is, no roll tables are used. The roller inserts the piece between the rolls; on the other side of the mill the catcher grasps the piece with his tongs as it comes through the mill and returns it either through the

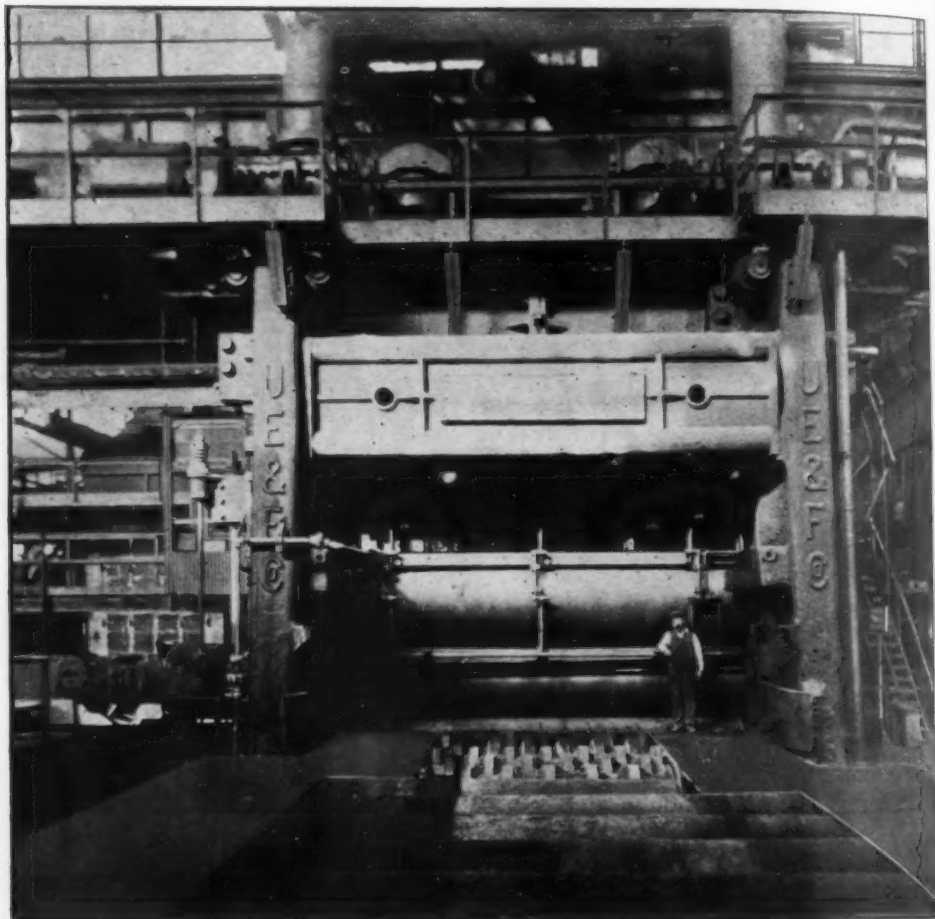


Fig. 8—Photograph of a 3-High Plate Mill.

upper pass if it is a three-high mill or over the top roll of a two-high mill.

#### COLD WORKING

In the mechanical treatment of steel at or slightly above atmospheric temperature two general procedures are used: (1) cold rolling; and (2) drawing. The former is used for bars and other sections  $\frac{3}{4}$  inch in diameter or larger. The latter is used for wire and for tubing.

Cold working results in greater strength, gives the metal a high surface finish, and produces a section accurate in size. The increase in strength, elastic limit, and hardness of the cold-worked material is accompanied by an increase in brittleness. Cold drawn wire becomes so brittle after three or four drafts that it must be annealed before it can be cold-worked further.

A most desirable structure results from cold work, followed by annealing at a temperature slightly below the critical range.

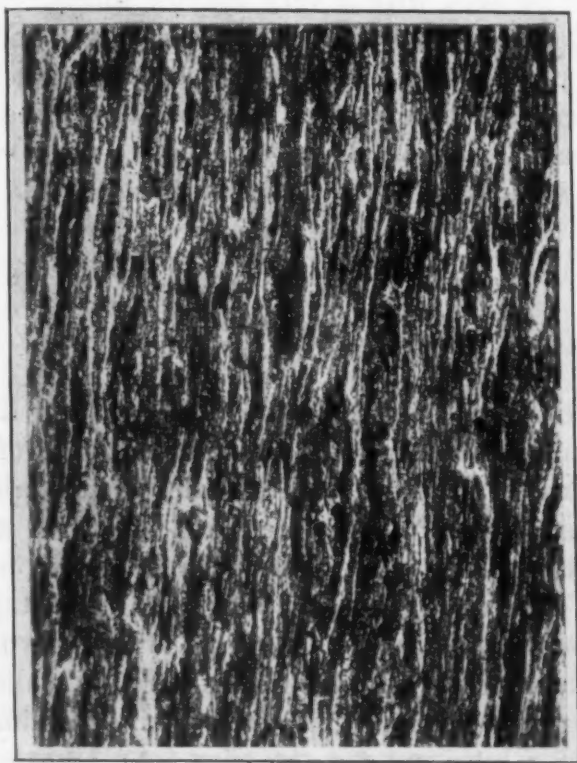


Fig. 9—Photomicrograph of a Polished and Etched Section of Cold Drawn Steel Wire.

As noted in a previous section, when mechanical pressure is applied to steel which is at a bright red heat, the crystals are crushed and broken. As long as the metal is above the critical temperature the crystals tend to coalesce into larger units, partly upsetting the effects of the work. When mechanical pressure is applied to steel which is slightly above atmospheric temperature the grains are distorted in the direction of working and do not reform into larger masses. If sufficiently worked the grains may be so distorted that no grain boundaries are in evidence.

### *Cold Rolling*

Cold rolling is used principally to impart a bright smooth surface to the steel and to have it finished accurately to size. Cold-rolled round bars are used for shafting, some tools, strip tool steel and the like. The bars are hot-rolled in the usual manner; they are then pickled in acid to remove scale and finally are given one or more passes through a pair of finishing rolls. The size may be kept within very narrow limits.

A considerable proportion of the thin sheet produced is given one or more passes to improve the finish and bring it to accurate size. The structure deformation due to cold rolling especially in the case of bars is felt on the surface only. Cold rolling in contrast to the drawing of wire does not increase the strength and hardness nor decrease the ductility appreciably.

### *Cold Drawing*

In wire drawing a hot-rolled rod, varying in diameter from  $\frac{1}{8}$  to  $\frac{3}{4}$  inch, depending upon the required size of the finished wire, is pickled in acid to remove scale, then washed in water, dipped in a solution of lime water, and baked at about 300 degrees Fahr. After baking, the end is pointed and pushed through the tapering hole in a wire drawing die. The tapered end is grasped by tongs and the whole coil of wire drawn through the die. The force necessary to draw wire through a die varies from 40 to 60 per cent of its ultimate strength. The lime coating on the rod acts as a lubricant for the wire. An additional lubricant such as grease, tallow, or soap is usually necessary.

The reduction in cross-section for each draft varies from 25 per cent for high carbon steels to as much as 45 per cent for very low carbon steels. The ductility of the steel as measured by the percentage elongation decreases very rapidly. After 3 to 4 drafts it is necessary to anneal the wire before it will withstand further cold work.

By varying the number of drafts, the amount of reduction in each draft, and by annealing at intervals, it is possible to secure almost any combination of physical properties desired.

In the manufacture of seamless tubes a steel billet is pierced

longitudinally through the center. It is then heated and passed over a mandril and through rolls. With each successive pass the hole becomes larger in size and the external diameter of the tube smaller, until the tube is brought to nearly the finished diameter and wall thickness. After cooling, the tube is pickled and cold drawn over a mandril and through rolls until the exact dimensions are obtained.

## Comment and Discussion

Papers and Articles Presented Before the Society and Published in Transactions Are Open to Comment and Criticism in This Column—Members Submitting Discussions Are Requested to give Their Names and Addresses

### ON HIGH POWER PHOTOMICROGRAPHY

By S. L. HOYT

THE principal point brought up by Mr. Lucas' work was resolving power, and its emphasis in my discussion<sup>1</sup> might give an erroneous impression of the true merits of the apochromatic objectives. The old or achromatic objectives have been made with a resolving power, as given by the numerical aperture, equal to that of apochromatic objective, and yet their performance is much poorer due to the aberrations. Abbe's real contribution was the elimination of spherical aberration for two wave-lengths, and of chromatic aberration for three wave-lengths, which enabled him to make full use of the high numerical aperture without the errors of aberration. If the aperture of the chromatic objective mentioned were reduced to that of the achromatic cone, i. e., to its useful aperture its resolving power would be materially less.

<sup>1</sup>"On High Power Photomicrography," by Dr. S. L. Hoyt, TRANSACTIONS, A. S. S. T., Vol. 8, July, 1925, page 95.

## The Question Box

A Column Devoted to the Asking, Answering and Discussing  
of Practical Questions in Heat Treatment — Members  
Submitting Answers and Discussions Are Requested  
To Refer to Serial Numbers of Questions

*QUESTION NO. 162. To what extent will un-annealed cold drawn bar stock distort as a result of carburizing and hardening parts made therefrom?*

*QUESTION NO. 163. What is the lowest temperature at which ingot iron or low carbon steel will carburize when packed with the usual type of commercial carburizer?*

*QUESTION NO. 138. Is the electrolytic pickling process being used to show up defects in steel bars? If so, how does it compare with the regular pickling processes?*

*QUESTION NO. 142. What is the consensus of opinion of the cause of blisters in low and high grade steels sheets?*

*QUESTION NO. 143. How can these blisters be eliminated?*

*QUESTION NO. 149. Do plates of basic open hearth steel ever have a higher base rate than acid open hearth steel?*

*QUESTION NO. 151. What effect does the temperature of an oil-quenching bath have upon the hardness of a piece of steel quenched into it from the proper hardening temperature?*

*QUESTION NO. 152. Is manganese up to 1.50 per cent detrimental in a steel to be used for carburizing purposes? How does the high manganese content affect the final product?*

*QUESTION NO. 160. Is there any salt or combination of salts, which will melt at or below 350 degrees Fahr.? Will this salt be stable?*

ANSWER. By L. C. Conradi, chief chemist, Spicer Mfg. Corporation, South Plainfield, N. J.

There are several grades of drawing or tempering salts which melt at 350 degrees Fahr. or under. The composition and behaviour of two such salts at 1000-1100 degrees Fahr. is given herewith. The melting points were taken in

a 100 cubic centimeter-crucible and may be slightly higher than values obtained by the regular capillary tube method. These salts which are here designated mixture No. 1 and No. 2 are regularly sold under trade names.

| COMPOSITION OF TEMPERING SALTS BEFORE AND AFTER HEATING IN IRON<br>CRUCIBLES IN AN ELECTRIC MUFFLE FURNACE FOR 192 HOURS |                   |                             |                             |
|--|-------------------|-----------------------------|-----------------------------|
| Mixture No. 1  | Before            | After 1100<br>degrees Fahr. | After 1000<br>degrees Fahr. |
| Melting Point  | 300 degrees Fahr. |                             |                             |
| KNO <sub>3</sub>   | 54.26 Per Cent    |                             |                             |
| KNO <sub>2</sub>   | 3.14              |                             |                             |
| NaNO <sub>3</sub>  | 41.07             | 6.27 Per Cent               | 18.6 Per Cent               |
| NaNO <sub>2</sub>  |                   |                             |                             |
| Na <sub>2</sub> O  | 0.06              | 2.07                        | 0.6                         |
| NaCl   | 0.32              |                             |                             |
| Moisture at 212°F  |                   |                             |                             |
| Mixture No. 2  | Before            | After 1100<br>degrees Fahr. | After 1000<br>degrees Fahr. |
| Melting Point  | 344 degrees Fahr. |                             |                             |
| KNO <sub>3</sub>   | 48.29 Per Cent    |                             |                             |
| KNO <sub>2</sub>   |                   |                             |                             |
| NaNO <sub>3</sub>  | 25.93             | 15.38 Per Cent              | 21.40 Per Cent              |
| NaNO <sub>2</sub>  | 23.42             |                             |                             |
| Na <sub>2</sub> O  |                   | 2.6                         | 0.15                        |
| NaCl   |                   |                             |                             |
| Moisture at 212°F.   | 0.63              |                             |                             |

At a temperature of 1000-1100 degrees Fahr. sodium and potassium nitrites are converted to their corresponding nitrates and the melting point of a bath of mixed nitrites and nitrates will with use approach the melting point of the mixed nitrates. A sample of sodium nitrite (CP) heated for 96 hours at 1000 degrees Fahr. showed an increase in weight of 11.4 per cent. A sample of potassium nitrate (CP) under same treatment showed a loss in weight of 1.66 per cent. This loss may be largely due to spattering.

**QUESTION NO. 161.** *What becomes of the excess carbon above that which can be combined with other elements to form austenite? What would be the form designation of such carbon and what effect would it produce as regards the structure and physical properties of the metal, assuming that other alloying constituents were present in sufficient quantity to reduce the factor of brittleness to within the range of lower carbon steels?*

## Abstracts of Technical Articles

### Brief Reviews of Publications of Interest to Metallurgists and Steel Treaters

**BALL BEARINGS IN THE MAKING.** By Ellsworth Sheldon, New England editor, *American Machinist*, in *American Machinist*, Vol. 63, No. 1, 1925, page 11.

This is the third article on this subject and discusses the assembling of the bearings; the press work on the cages; cleaning, testing and inspecting. Tests for noise and magnetism are also covered. The previous articles dealt with the various stages through which the balls and rings of ball bearings pass before they reach the stockroom.

**REPLACING OIL WITH ELECTRICITY.** By W. J. Walsh, manager, Delta File Works, Philadelphia, in *Iron Age*, Vol. 116, No. 3, 1925, page 145.

This article tells how an oil-fired heat-treating furnace was converted into an electric furnace, and gives the relative cost, advantages and the results.

**MAKING CAST STAINLESS STEEL.** By J. M. Quinn, in *Iron Trade Review*, July 23, 1925, page 185.

This article discusses how corrosion resistant metal may be made economically in an electric furnace, and states that slag control is of the greatest importance in the success of the work. Detail costs are given.

**SOME METHODS FOR COOLING QUENCHING OIL.** By Kenneth B. Millett, in *Forging-Stamping-Heat Treating*, July, 1925, page 232.

This article states that it is important that the temperature of a quenching bath be kept as nearly constant as possible in order to insure uniformity of results in heat treatment.

**DIE PERFORMANCE IN MANUFACTURE OF NUTS.** By Arthur L. Greene, Buffalo Bolt Company in *Forging-Stamping-Heat Treating*, July, 1925, page 241.

The author discusses in detail the function of various punches and dies in the continuous process manufacture of cold worked square and hexagon nuts.

**ELECTRIC ANNEALING OF STEEL.** By Harold Fulwider, manager, industrial heating sales, General Electric Co., Schenectady, N. Y., in *Iron Age*, Vol. 116, No. 6, 1925, page 342.

This article was taken from a report prepared for and included in the power committee report of the National Electric Light Association, presented

at San Francisco, June 15 to 19, and describes four types of furnaces now in operation for aging, normalizing and annealing castings, giving illustrations of each.

**EFFICIENCY OF HEATING FURNACES.** By E. H. Kotnig, engineer, Peerin & Marshall, consulting engineers, New York City, in *Iron Trade Review*, July 30, 1925, page 249.

The above article compares the performance of the continuous and the intermittent types of heating furnaces, and the comparison indicates the duties for which each is best fitted. A close study of the performance of the furnace might influence the design.

**FORGING CRANKSHAFTS FOR LARGE DIESEL ENGINES.** By Fred H. Colvin, editor, *American Machinist*, in *American Machinist*, Vol. 63, No. 1, 1925, page 3.

This article tells of some of the problems in producing heavy crankshafts in large quantities and the methods by which satisfactory, uniform results are secured.

**PHOTOELASTICITY AND ITS RELATION TO GEAR WHEELS.** By A. L. Kimball, Jr., research laboratory, General Electric Co., Schenectady, N. Y., in *American Machinist*, Vol. 63, No. 1, 1925, page 7.

The author of this article describes methods and instruments used in determining stress distribution on gear teeth under static load. Results of stress in celluloid models easily transferred to steel, are given.

**OPERATION AND APPLICATION OF THE BALL BEARING.** By T. C. Delaval-Crow, chief engineer, New Departure Mfg. Co., in *American Machinist*, Aug. 20, 1925, page 295.

This article compares the qualifications of the ball bearing with the plain bearing, and describes the action between balls and races. Examples of successful application are given.

**SOME NOTES ON DURALUMIN FORGING.** By H. A. Whiteley, in *Forging-Stamping-Heat Treating*, August, 1925, page 260.

The above article was reprinted from the Journal of the (British) Association of Drop Forgers and Stampers. The author discusses in a very comprehensive manner, the working of duralumin and states that forging duralumin introduces many difficulties not encountered with steel.

**WHY HARD CHILLED ROLLS BECOME ROUGH.** By Harold Harris, Woodlawn, Pa., in *Forging-Stamping-Heat Treating*, August, 1925, page 275.

The author tells how to eliminate many failures by careful warming of the rolls as well as the careful use of water. He states that the uniformity of roll temperature is essential for successful operation.

## Reviews of Recent Patents

By

NELSON LITTELL, Patent Attorney

110 E. 42nd St., New York City

Member of A. S. S. T.

Through the courtesy of Nelson Littell, we have secured an additional library service for members of the A. S. S. T. This service comprises the selecting and supplying of copies of current patents, on specified subjects, as they are issued by the Patent Office.

Mr. Littell will review the Official Gazette each week, selecting those patents on subjects desired by individual subscribers, and order separate copies mailed directly to them from the U. S. Patent Office. Subscribers may specify the field of patents in which they would be interested in receiving current information on, or they may supply a list of their products and manufacturing processes whereby Mr. Nelson could judge as to what patents would be of interest to them.

The cost for this service is \$10.00 per year, plus 10 cents per copy for each copy of a patent furnished.

**1,545,305, Metal-Treating Apparatus and Process, Frederick M. Crapo, and William Baylis, of Muncie, Indiana.**

This patent describes a process and apparatus for annealing, case hardening and coating continuous flexible materials, such as wires, rods, or the like. For the case hardening material a molten cyanide mixture is used, and to prevent the cyanide mixture from attacking the walls of the pot and

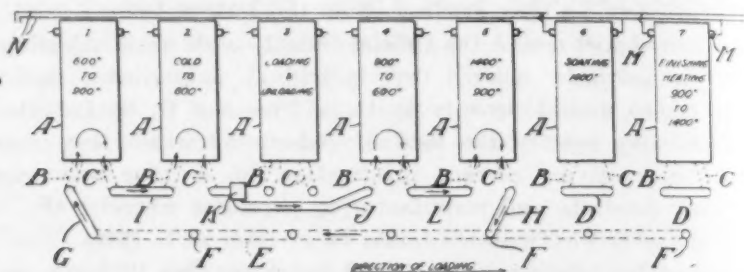


from losing its case hardening properties, it is confined by means of a band or ring 16 to a specified location in a pot of molten lead 12. The cyanide mixture floats upon the lead and in this way is kept from contact with the walls of the pot, so that the only replacement necessary is the comparatively inexpensive ring 16. The wire or rod 10 is first passed through the molten lead in the pot 12, where it is heated to the proper case hardening temperature and is then passed through the cyanide mixture 15 enclosed in the ring 16. From this it is passed through a bath of water 17 for removing any of the adhering salts and through a suitable flux such as hydrochloric acid 18,

then over a drying pan 19 and into the bath 20 of molten zinc, in which it is coated and then wound upon the reel 21. The floating of the salt mixture upon the bath of molten lead inside the band 16 reduces the amount of salt necessary, reduces the loss of the salts, reduces the destruction of the containers and the preliminary heating in the lead bath improves the case hardening effect of the cyanide.

**1,546,532, Method of Annealing, Thaddeus F. Baily, of Alliance, Ohio.**

This patent describes the method of annealing wherein an inert gas is circulated through a plurality of annealing hoods in such a way that the gas from the hoods of higher temperature may be utilized in heating the hoods of a lower temperature. The system comprises a plurality of hoods A adapted to receive the inert gas through a continuous circulating system, including



the pipes B and C. Means, such as a detachable pipe section J, are provided for cutting one hood out of the circulating system to permit of loading or unloading articles being treated therein and the position of the loading and unloading hood may be shifted around the circuit by moving the detachable pipe section J from point to point. In this way the heat of the hoods progress systematically around the circuit in closed cycles. For imparting additional heat to the hoods requiring higher temperatures, electrical conduits N are provided for conveying electric heat into the terminals M of the hood.

**1,546,881, Zirconium Steel and Process of Making Same, Frederick M. Becket, of New York, N. Y., Assignor to Electro Metallurgical Company, of New York, N. Y., a Corporation of West Virginia.**

This patent describes the process of reducing the brittleness in high phosphorus steels so as to render them acceptable under the usual engineering specifications by adding zirconium to said high phosphorus steel. The invention is carefully distinguished from the use of zirconium purely as a deoxidizer and scavenger for steel and rests upon the discovery that zirconium when added to high phosphorus steels in suitable proportions will exert an heretofore unsuspected beneficial effect upon the mechanical and physical properties of such steel. The effect is best measured by the Izod notched-bar impact test, the readings of which are inversely proportional to the brittleness of the steel. The zirconium is added to the high phosphorus steel in the ladles as a compound of zirconium-ferrosilicon or silicon-zirconium. About 0.15 per cent by weight of zirconium is used with a steel containing 0.80 per cent carbon. The Izod number indicating the brittleness of untreated low

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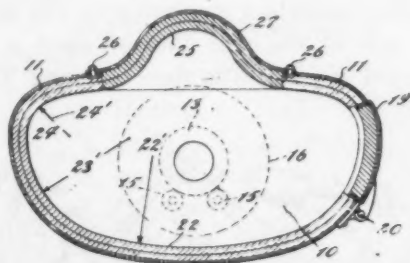
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phosphorus steel and the Izod number for the zirconium treated high phosphorus steel substantially coincide, which shows that the zirconium added has completely counteracted the embrittling effect of the phosphorus.

**1,546,965, Process for Producing Wrought Metal, Edgar F. Blessing, of East Orange, New Jersey.**

This patent describes an apparatus for producing wrought iron which comprises a regular shaped casing 11, provided with doors 19 and 27 and suspended on a horizontal axis around which it may be rotated on hollow trunnions 13, to effect a mixing of the slag and iron therein. The furnace and doors are provided with suitable heat resisting linings to protect the casing 11. Fuel burners are provided for heating the furnace through the hollow trunnion 13. In operation, the furnace is charged in the position shown with molten iron and oxidizing slag and the charge melted and the



furnace rocked back and forth to cause the thorough mixture of the slag and iron. When the refining and mixing process is complete, shortly before the iron becomes welded into a mass, the furnace is turned approximately 90 degrees in a counter clockwise direction to bring the charge onto the furnace walls 23' and 24' of the furnace. Here the charge is rocked back and forth over the abrupt portion 24 to cause thorough mixing and balling of the charge, while the continued play of the flame through the trunnions 13 burns out the remaining portion of the carbon and other impurities. When the iron is ready to "ball" the furnace is turned through an additional 90 per cent to bring the balling section 25 to the bottom and deposit the charge therein. The contact of the particles in the hemispherical balling section 25 causes all parts of the charge to cohere the entire mass forming into a spongy ball, which after a short time can be discharged through the door 19 by turning the furnace through an additional 90 degrees.

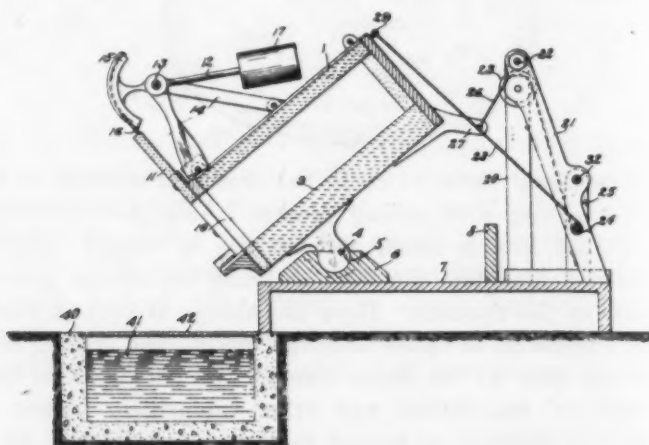
**1,549,207, Carburization of Metals, Howard R. Miner, of Los Angeles, California, Assignor to California Cyanide Company, Incorporated, of New York, N. Y., a Corporation of Delaware.**

This patent describes a cheap and effective case hardening compound, which comprises a mixture of carbon, particularly gas or petroleum carbon impregnated with cyanide, with or without other constituents. Such a case hardening compound combines the cheapness of carbon with the case hardening efficiency of cyanide. The preferred composition includes sodium cyanide 20 per cent, sodium carbonate 20 per cent, caustic soda 10 per cent and

approximately 45 per cent carbon. An effective way of producing the mixture is by synthesizing the cyanide directly into the mixture by heating approximately 50 parts of sodium carbonate, 50 parts of coke or gas carbon and approximately 2 per cent of iron oxide to approximately 1100 degrees Cent, while passing a stream of nitrogen or nitrogenous gas therethrough, so that the nitrogen is fixed in the form of a cyanide and a product is obtained which closely approximates the composition given above. The case hardening process consists in packing the articles to be treated in this mixture, enclosed in a suitable box, and heating to a temperature of 900 to 950 degrees Cent, for a period required to produce the desired depth of case.

**1,549,463, Heat-Treating Furnace, John W. Dierdorf, of Canton, Ohio.**

This patent describes a heat-treating furnace comprising a box like structure with a flat bottom 9 which is normally in horizontal position. The box is pivoted upon a rounded knuckle 4 journaled in the socket 5 and in normal position is adapted to rest at the rear thereof upon a stationary support 8. A sliding door 11 is used to close the door opening 10 and is operated by



means of a segment 16, lever 12 and counter weight 17 to open and close the door when the furnace is tilted to and from discharging position. Cables 26 and 28 are attached to the rear of the furnace and at the end of the projection 27 and at the eye 29 and are passed over suitable pulleys 23 and secured to a windlass 24, which may be rotated to tilt the furnace about the knuckle 4. Holes are provided through the walls of box 1 for heating and suitable gas or oil flame is projected into the box through nozzles adjacent to these holes, but disconnected from the box itself. A quenching tank 40, containing suitable oil or water quenching solution, is located at the front of the furnace and is provided with a removable plate 42, so that in the use of the furnace, after the articles therein have been heated to the desired temperature they may be discharged upon the cover 42 for cooling in air, or they may be dropped into the quenching solution 41 by removing the cover 42 from the tank 40.

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## News of the Chapters

### STANDING OF THE CHAPTERS

IN the August issue of *TRANSACTIONS* appeared a relative membership standing of the 29 chapters of the Society as of June 1, 1925, and as of July 1, 1925. The tabulation which appears below shows the relative membership standing of the chapters on July 1, 1925, and August 1, 1925.

It will be noted that there is no change in the relative position of the chapters in Group I, Group II, or Group III.

#### Standing as of August 1

##### GROUP I

1. Detroit (371)
2. Cleveland (319)
3. Pittsburgh (290)
4. Chicago (263)
5. Philadelphia (258)
6. Boston (223)
7. New York (204)

##### GROUP II

1. Hartford (122)
2. Lehigh Valley (98)
3. Golden Gate (95)
4. Cincinnati (73)
5. Syracuse (71)
6. Milwaukee
7. St. Louis
8. Indianapolis
9. Buffalo
10. Northwest

##### GROUP III

1. Tri City (66)
2. Rochester (60)
3. Los Angeles (60)
4. New Haven (56)
5. Schenectady (50)
6. Washington
7. Worcester
8. Rockford
9. Providence
10. Toronto
11. Springfield
12. South Bend

#### Standing as of July 1

##### GROUP I

1. Detroit (360)
2. Cleveland (314)
3. Pittsburgh (292)
4. Chicago (265)
5. Philadelphia (260)
6. Boston (223)
7. New York (203)

##### GROUP II

1. Hartford (126)
2. Lehigh Valley (98)
3. Golden Gate (93)
4. Cincinnati (76)
5. Syracuse
6. Milwaukee
7. St. Louis
8. Indianapolis
9. Buffalo
10. Northwest

##### GROUP III

1. Tri City (66)
2. Rochester (62)
3. Los Angeles (61)
4. NEW HAVEN (56)
5. SCHENECTADY
6. Washington
7. Worcester
8. ROCKFORD
9. Providence
10. Toronto
11. SPRINGFIELD
12. South Bend

Detroit maintains its lead in first position with a total of 371 members, a lead of 52 over its nearest rival, Cleveland. Through the activities of its membership committee Detroit has a total membership never exceeded by any

chapter of the society. Detroit is receiving and deserves commendable commendation.

The News of the Chapters section of TRANSACTIONS is again unusually small in this issue, but is due to the fact that practically all of the chapters do not hold meetings during the months of June, July, August and September.

The August meeting of the Golden Gate Chapter was held on Saturday, the 15th, at the Engineers Club, San Francisco. Frank B. Drake, the chairman, presided, and the attendance was in the number of forty-three men.

After the secretary's report, the chairman of the program committee, J. S. Fowler, described the tentative program that had been laid out for the winter on the basis of two talks at every meeting. The first talk is to be on the subject of a process of heat treating such as carburizing, hardening, etc., and the second talk will primarily be concerned with finished products, such as dies and tools, saws, sheet steel, etc. In this way a fairly broad field will be covered much more in detail than was possible in last winter's series of related talks on the whole subject of steel—from ore to finished product.

The chairman then called upon an eastern visitor—H. F. Wood of the Ingalls-Shepard Division of the Wyman Gordon Company of Chicago—for a few words.

The first speaker of the evening was J. H. Knapp of the James H. Knapp Company of Los Angeles, who had for his subject "Heat Treating Furnaces." This is naturally a subject of prime interest to every heat treater, and Mr. Knapp's broad experience enabled him to present his talk with great clearness and simplicity. This was the ninth and last of our series on Steel.

The second event of the evening was a paper by J. W. Monerieff, ceramic engineer of the Stockton Fire Brick Company on "Refractories for the Heat Treating Furnace." The discussion following this talk proved of value to all present, emphasizing the lack of discriminating use of types of fire brick in various furnaces and the possibilities from a careful study of this subject on the part of the furnace user.

*D. Hanson Grubb.*

ADDRESSES OF NEW MEMBERS OF THE AMERICAN SOCIETY FOR  
STEEL TREATING

EXPLANATION OF ABBREVIATIONS. M represents Member; A represents Associate Member; S represents Sustaining Member; J represents Junior Member; and Sb represents Subscribing Member. The figure following the letter shows the month in which the membership became effective.

## NEW MEMBERS

- ASHMAN, R. G., (S-8), J. D. Crosby Co., Pawtucket, R. I.  
 BRIGGS, J. C., (M-7), Denver Rock Drill Mfg. Co., Denver, Colo.  
 BUTTERFIELD, F. W., (M-8), hardener, General Electric Co., Lynn, Mass.; *mail* 3 Seaside Terrace, East Lynn, Mass.  
 BUTTS, C. H., (M-7), Newton Steel Co., Newton Falls, Ohio.  
 BROPHY, OSCAR, (A-8), electric furnace engineer, American Resistor Corp., Philadelphia.  
 CLARKE, L. R., (Jr-8), student, Northwestern University; *mail* 450 Green St., Cambridge, Mass.  
 CRAM, T. B., (A-8), manager, industrial furnace division, Drying Systems, Inc.; *mail* 11 South Dusplaines St., Chicago.  
 DAVENPORT, E. S., (M-8), metallurgist, Westinghouse Lamp Co.; *mail* 70 Franklin St., Bloomfield, N. J.  
 DICKENSON, J. H. S., (M-7), research metallurgist, Vickers, Ltd., River Iron Works, Sheffield, England.  
 DOW, J. A., (M-8), foreman, heat treating department, Canadian Acme Screw & Gear Co.; *mail* 188 St. John's Road, Toronto, Canada.  
 DUCK, F. J. G., (M-8), instructor in metallurgy, Lehigh University, Bethlehem, Pa.  
 DUNN, L. C., (A-7), distributor, E. F. Houghton & Co.; *mail* 5324 Burns Ave., Detroit.  
 EVANS, C. D., (Jr-8), laboratory assistant, Westinghouse Electric & Manufacturing Co.; *mail* 2558 South 66th St., Philadelphia.  
 FAERY, F. W., (A-7), Park Chemical Co., 3417 Lovett St., Detroit.  
 FRANCIS, F. T., (M-8), pyrometer operator, treating room, Park Drop Forge Co.; *mail* 1677 East 93rd St., Cleveland.  
 FRASER, J. A., (Jr-6), student, University of Pittsburgh; *mail* 610 Bellaire Ave., Pittsburgh.  
 GREENE, E. G., (M-6), superintendent, Ferry Cap & Set Screw Co., 2151 Seranton Road, Cleveland.  
 HARDING, C. E., (M-6), superintendent, Whitinsville Spinning Ring Co.; *mail* 8 Fletcher St., Whitinsville, Mass.  
 HARRMAN, C. R., (M-7), Webster Hall, Detroit.  
 HENDERSON, H. P., (Jr-7), student, Massachusetts Institute of Technology, Cambridge, Mass.; *mail* 517 Broadway, Everett, Mass.  
 KATTO, A., (M-6), research engineer, Chatsu 10, Muroran, Hokkaido, Japan.  
 LAY, R. P., (M-8), chief engineer, Penn Spring Works, Baldwinsville, N. Y.; *mail* 131 Fellows Ave., Syracuse, N. Y.  
 LEVY, N. B., (M-8), laboratory assistant, Pittsburgh Crucible Steel Co.; *mail* P. O. Box 74, Midland, Pa.

- LUIN, C. V., (A-8), salesman, Crucible Steel Company of America, Cincinnati, Ohio; *mail* 3902 Montgomery Ave., Norwood, Ohio.
- MACDONALD, (M-7), chemist, Chicago Pneumatic Tool Co., Detroit; *mail* 4047 Buckingham Road, Berkley, Mich.
- MARANDE, W. F., (M-5), metallurgist, Wilcox Motor Parts & Manufacturing Co.; *mail* 1163 South 4th St., Saginaw, Mich.
- MARSH, H. S., (M-7), metallurgical engineer, Sharon Steel Hoop Co., Youngstown, Ohio.
- MILDORF, O. R., (M-7), general superintendent, Western Machinery Co., 900 North Main St., Los Angeles, Calif.
- MILLER, L. C., (M-5), in charge of metallurgical laboratory, United Alloy Steel, Corp.; *mail* 3206-6th St., Canton, Ohio.
- MOORE, F. C., (M-8), president, Canton Forge & Axle Co.; *mail* 2027 Dueber Ave., Canton, Ohio.
- MURPHY, W. J., (M-6), heat treating foreman, Ferry Cap & Set Screw Co., 2151 Seranton Road, Cleveland.
- ORNITZ, N. B., (M-8), metallurgist, Babcock Wilcox Co.; *mail* 3411-5th Ave., Beaver Falls, Pa.
- PAULSSON, N. A. V., (S-8), president, Uddeholm Company of America, 32 Vanderbilt Ave., New York City.
- PECK, C. A., (M-8), foreman, heat treating and hardening department, Barber Colman Co.; *mail* 324 North Horsman St., Rockford, Ill.
- PETERS, R. J., (M-7), chemist-metallographist, Warner Gear Co.; *mail* 308 North Tally, Muncie, Indiana.
- POWELL, G., (M-8), tool hardener, Westinghouse Electric & Manufacturing Co.; *mail* 48 St. Paul Ave., Newark, N. J.
- REID, L. F., (M-4), E. F. Houghton & Co., Lumpkin & D. T. Ry., Detroit.
- RHODES, C. C., (M-6), tool designer, Chevrolet Motor Co.; *mail* General Delivery, Flint, Mich.
- ROSS, D. E., (S-7), vice-president and general manager, Ross Gear & Tool Co., Lafayette, Ind.
- RUTH, H. V., (A-7), special steel representative, Ducommun Corp., Los Angeles; *mail* 755 Alfred St., Hollywood, Calif.
- SCHERMER, N. H., (A-7), sales metallurgist, E. F. Houghton & Co.; *mail* 55 Colorado St., Highland Park, Mich.
- SCOTT, J. H., (M-10), engineer, Richmond Forgings Corp., Richmond, Va.
- SMITH, H. M., (A-4), salesman, Cleveland Electric Illuminating Co., 908 Illuminating Co., 908 Illuminating Bldg., Cleveland.
- SNYDER, C. C., (M-8), metallographer, United Alloy Steel Corp.; *mail* 309 Harrison Ave., N. W., Canton, Ohio.
- WATSON, E. F., (M-7), heat treater and welder, Western Machinery Co.; *mail* 1310 West 70th St., Los Angeles, Calif.

## Items of Interest

A COMMUNICATION recently received from Dr. Albert Sauveur records the changes which have been made in the course of instruction in metallurgy at Harvard University. The communication states that instruction in metallurgy in the Engineering School of Harvard University will be hereafter conducted exclusively as post-graduate studies, which will be open to graduates of universities, colleges, and technical schools of recognized standing, who have the necessary knowledge of mathematics, chemistry, and physics; a knowledge of mineralogy is also desirable. A one-year program is offered in ferrous metallurgy, including courses in physical chemistry, general metallurgy, principles of metallography, metallography of iron and steel, metallurgy of iron and steel, physics of metals and alloys. About one-quarter of the year's work is devoted to training in research. A parallel one-year program in non-ferrous metallurgy is offered, including courses in non-ferrous metallurgy and metallography. Either of these one-year programs taken alone leads to the degree of Master of Science in Metallurgy.

A two-year program combining both ferrous and non-ferrous metallurgy and leading to the degree of Metallurgical Engineer is also offered. This program consists of all the formal courses of both of the one-year programs, which make up about two thirds of the work of the two years; the remainder is devoted to research.

The scientific training in physics, chemistry, and mathematics necessary to take up the professional study of metallurgy can usually be had in the colleges or technical schools. It is believed that suitably qualified college graduates may profitably proceed directly with their metallurgical studies, and that they should not be required to go through the usual four-year program, consisting for the most part of subjects, valuable in themselves, but which are rarely, if ever, pertinent to the work of the modern metallurgist. The students of metallurgy ordinarily aim to qualify themselves to take charge of metallurgical operations or to conduct metallurgical research, or, perhaps, to teach the subject. It is believed that at this stage of their educational career, i. e., after the completion of a college course of study or an engineering program, they should be able intelligently to decide whether they wish to enter the field of ferrous or non-ferrous metallurgy, and that one year of intensive graduate work in one of these fields should ordinarily fit them well to begin their lifework as practical metallurgists or research workers.

This departure from the old and time-honored custom of prescribing some sixteen to twenty courses, many of them irrelevant to the subject, for those wishing to qualify themselves for the metallurgical profession, should mark a step forward in technical education which, it is believed, will be appreciated and welcomed by many.

G. A. Lennox has been appointed assistant general sales manager of the Driver-Harris Co., Harrison, N. J., manufacturer of special alloys, with head-

quarters at the main office and plant. Mr. Lennox has been with the company for a number of years, in recent years being engaged in selling and application work. He was district manager for some years at Chicago and later was in New England and northern New York.

W. J. Priestley, formerly in Pittsburgh as metallurgical engineer for the Electro Metallurgical Sales Corp., has been transferred to the home office, 30 East Forty-second Street, New York, as assistant general sales manager of this company and in similar capacity for the electrode division of the National Carbon Co.

R. S. Poister, formerly with the United Alloys Steel Corp., Canton, O., and now with the Alan Wood Iron & Steel Co., Norristown, Pa., has been employed to succeed Mr. Priestley Oct. 1 as metallurgical engineer in Pittsburgh.

W. J. Crook, of Stanford University, San Francisco, Cal., on July 15, finished his trip through the east in connection with the establishment of an Ordnance Section, Reserve Officers Training Corps, at Stanford University. This section will begin operation in October, 1925. The particular object of the trip was to establish a contact between the Ordnance Department officers and the engineering faculty at Stanford and to obtain a general idea of the activities of this department at the various arsenals and the best methods of Ordnance instruction. Mr. Crook visited the War Department at Washington; Aberdeen Proving Grounds, Maryland, where a Reserve Officers Training Corps summer ordnance camp is in session; Watertown Arsenal, Boston; and the Picatinny Arsenal, N. J., where propellant powder is being manufactured. He also spent some time at Pittsburgh making observations for the Pacific Coast Steel Co., of which he is the consulting metallurgical engineer. From there he went to the Rock Island Arsenal and the steel casting plant at Davenport, Iowa. He expects to return to San Francisco during the early part of August.

G. E. Pollard, who has been connected with the Columbia Steel Corp., at Provo, Utah, is now located in Culver City, Cal.

The American Metallurgical Corporation announce that they recently either shipped or received orders from the following concerns for electric furnaces.

30 K.W. Semi-Continuous Annealing Furnace, Shur-On Optical Company, Rochester, N. Y.

15 K.W. Box Type Furnace, Buchanan & Bolt Wire Co., Holyoke, Mass.

20 K.W. Cyanide Pot Furnace, Moore Drop Forging Co., Chicopee, Mass.

30 K.W. Box Type Furnace, O. K. Tool Company, Shelton, Conn.

30 K.W. Box Type Furnace, Norton Company, Worcester, Mass.

75 K.W. Box Type Furnace, Norton Company, Worcester, Mass.

30 K.W. Cyanide Pot Furnaces, New Britain Machine Co., New Britain, Conn.

15 K.W. Lead Pot Furnace, Arrow Electric Company, Hartford, Conn.

20 K.W. Cyanide Pot Furnace, The Cushman Chuck Co., Hartford, Conn.

30 K.W. Box Type Furnace, The Perkins Appliance Co., Springfield, Mass.

20 K.W. Cyanide Pot Furnace, The Perkins Appliance Co., Springfield, Mass.

1925

The Westinghouse Electric Co. of Japan is the title of a new company organized by Westinghouse interests for distributing Westinghouse products directly to the Japanese and for servicing Japanese users of the company's products. The new company is a subsidiary of the Westinghouse Electric International Co. Officers are: Chairman, Guy E. Tripp; president, L. A. Osborne; vice-president, E. D. Kilburn, and I. F. Baker is managing director, located at Tokio. The staff in Japan will be entirely Japanese. It was a simple matter to assemble this staff because scores of Japanese engineers have been employed at the Westinghouse works at East Pittsburgh and elsewhere.

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M. L. Frey, formerly assistant metallurgist for the Holt Mfg. Company of Peoria, Ill., has accepted a position as metallurgist for the Gerlinger Electric Steel Casting Co., West Allis, Wis.

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The W. N. Best Corporation, 11 Broadway, New York, pioneer manufacturers of Oil Burners and Oil Burning Furnaces, announce the purchase of the Dempsey Furnace Company, Jersey City, N. J. The combined furnace business of the two companies will be operated as the Dempsey Furnace Division of the W. N. Best Corporation, and will be carried on under the personal direction of Mr. H. B. Dempsey.

Mr. Dempsey has had twenty years of practical experience in the design and manufacture of industrial furnaces for Heat Treating, Annealing, Hardening, Carbonizing, Tempering, Forging, Welding, Galvanizing, Smelting, Rivet, Angle, Plate and Bolt Heating.

With the addition of the well known Dempsey line of standardized industrial furnaces to the engineering and manufacturing facilities of the W. N. Best Corporation, the scope of the field covered and the ability to render a more complete service in every phase of industrial oil burning is increased to the maximum.

The W. N. Best Corporation have just completed their thirty-fifth year in the liquid fuel business.

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Horace C. Knerr announces his resignation as chief metallurgist at the U. S. Naval Aircraft Factory to engage in professional practice as consulting metallurgical engineer, specializing in heat treatment and metallography of steel and light alloys. His address will be 1500 Green St., Philadelphia.

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Robert J. Anderson offers a general consulting engineering service in the metallurgy, production and application of aluminum and aluminum alloys. Complete advice may be obtained by manufacturers and users on all phases from raw materials to finished products. The variety of service offered is as follows: advice and information on aluminum ores (bauxite), alloys, duralumin, electrical applications, fabrication and stamping, foundry practice, heat treatment, melting and furnaces, motor car applications, permanent-mold work, rolling-mill practice, secondary metal and scrap, uses, etc. Service covers development work, examinations, expert testimony and patent litigation, facts finding, investigations, management, opinions, organization, production, reports, research, surveys for financial interests, technical-control methods, tests,

valuations, etc. Inquiries for information on any phase of aluminum will receive prompt attention by addressing them to 221 Amber Street, East, Pittsburgh.

E. A. Hitchcock, dean of the College of Engineering, Ohio State University, announces that there will be inaugurated a department of industrial engineering connected with the College of Engineering next fall. John Younger, member, A. S. S. T., formerly chief engineer, truck division, Pierce Arrow Motor Car Co., chief of engineering division, Motor Transport Corporation, and vice-president Standard Parts Co., will head the new department.

The proposed course is designed to prepare engineering students for future engineering executives and to give a broad view of administrative problems. The foundation of this education will be the standard course in fundamental engineering principles and the remainder of the work will be treated from the engineering side of factory problems.

Clifford B. Bellis, formerly a member of the editorial staff of *Chemical and Metallurgical Engineering*, has opened an office as a consulting metallurgist, at 161 Milk Street, Boston. He specializes on steel and its heat treatment, industrial heat problems and technical publicity writing.

N. A. V. Paulsson, for several years chief engineer of the Ludlum Steel Co. and of Corning & Co., Watervliet, N. Y., has become president of the newly formed Uddeholm Co. of America, Inc., 52 Vanderbilt Avenue, New York. The new company will handle Swedish steels.

Edward Busch has been appointed district manager in Ohio and Indiana for the Hevi Duty Electric Co., of Milwaukee, Wis. Mr. Busch will have a permanent headquarters at 879 Arcade, Cleveland.

T. D. Lynch, manager of the material and process engineering department, Westinghouse Electric & Mfg. Co., was elected a member of the board of directors of the American Society for Testing Materials at the recent annual convention in Atlantic City. This is the second similar honor given to Mr. Lynch by engineering bodies, he having been president of the American Society for Steel Treating in 1922-23. He had been with the Westinghouse company since 1899. He was graduated from the University of West Virginia, and during the Spanish-American war served in the bureau of steam engineering of the United States navy.

H. D. McKinney has been elected second vice-president and general sales manager of the Driver-Harris Co., Harrison, N. J. Mr. McKinney came to the Driver-Harris Co. in 1918 as district sales manager of the New England territory, in which capacity he served until 1920 when he was transferred to the Chicago sales office as manager. Prior to going with the Driver-Harris Co., Mr. McKinney was associated with the Westinghouse Electric and Manufacturing Co.

(Continued on Page 34 Adv. Sec.)

## EMPLOYMENT SERVICE BUREAU

The employment service bureau is for all members of the Society. If you wish a position, your want ad will be printed at a charge of 50c each insertion in two issues of the Transactions.

This service is also for employers, whether you are members of the Society or not. If you will notify this department of the position you have open, your ad will be published at 50c per insertion in two issues of the Transactions. Fee must accompany copy.

### Important Notice

In addressing answers to advertisements on these pages, a stamped envelope containing your letter should be sent to **AMERICAN SOCIETY FOR STEEL TREATING**, 4600 Prospect Ave., Cleveland, O. It will be forwarded to the proper destination. It is necessary that letters should contain stamps for forwarding.

### POSITIONS WANTED

**EXPERIENCED METALLOGRAPHIST** desires position. Has had practical experience in heat treating, foundry and metallurgical research work. Technical graduate in mechanical engineering. Best of references. Address 8-5.

**METALLURGIST**—Young Chinese interested in physical metallurgy and metallography from the standpoint of physics, desires position as assistant research laboratory. Age 23 and graduated from technology school. Prefer to work on problems of iron and steel. Can furnish excellent references. Address 9-15.

**CHEMICAL ENGINEERING AND METALLURGICAL** graduate desires position. Has had five years' experience in the metallurgy of iron and steel, research, testing, heat treatment and inspection. Location immaterial. Excellent references. Address 9-5.

**EXPERIENCED METALLOGRAPHIST** desires position. Has had practical experience in heat treating, foundry and metallurgical research work. Technical graduate in mechanical engineering. Best references. Address 8-5.

### POSITIONS OPEN

**INDUSTRIAL LABORATORY** has opening for a chemist and metallographist. It is believed that the right man can develop the metallographic work to the point where it will require his entire time, but at present he will be expected to handle analytical work in addition. Please give full information as to experience, references, etc., in replying. Address 8-1.

**WANTED:** Competent man to take charge of a commercial heat treating plant in the Cleveland district. A good position for the right man. Must have had an all-around heat treating experience including carburizing and hardening of tool and high speed steel. Prefer married man 35 to 40 years of age. Address 9-10.

**WANTED, A MAN** who is thoroughly familiar with tool steel and can sell same, age 25-40, preferably married, to take charge of Chicago warehouse-business, good proposition will be given to the right man who can run business with financial support. Address 9-25.

### WANTED

**WANTED:** Used Rockwell Hardness Testing Machine, Model 2½ A. Address 8-10.

**WANTED:** Brinell Machine. State make, model, condition and lowest price. Address 9-1.

A. E. R. Turner, formerly manager of the machine tool plant of the John Bertram & Sons Co., Ltd., has been appointed manager in charge of the Cleveland office of the Niles-Bement-Pond Co., succeeding B. A. Tozzer.

### THE IRON INDUSTRY IN 1924

Considerably less iron ore, pig iron, and ferroalloys were produced and shipped in the United States in 1924 than in 1923, according to figures compiled by Hubert W. Davis, of the Bureau of Mines, and just made public by the Department of Commerce.

#### Iron Ore

The iron ore mined in 1924 amounted to 54,267,419 gross tons, a decrease of 22 per cent as compared with 1923. Of the 20 States producing iron ore in 1924, only five—Alabama, Missouri, Ohio, Utah, and Washington—contributed more ore than in 1923. The shipments of iron ore in 1924 amounted to 52,083,375 gross tons, valued at \$151,307,105, a decrease in quantity of 25 per cent and in value of 37 per cent as compared with 1923. The average value per ton of iron ore at the mines in 1924 was \$2.91, which is 54 cents less than in 1923. The stocks of iron ore at the mines at the end of 1924 amounted to 12,410,619 gross tons, compared with 10,165,875 tons at the end of 1923, an increase of 22 per cent.

Iron ore mined in the United States in 1923 and 1924  
(in gross tons)  
(Exclusive of ore containing 5 per cent or more of manganese)

| State                | 1923       | 1924       | Percentage of increase or decrease in 1924 |
|----------------------|------------|------------|--|
| Alabama .....        | 6,783,146  | 6,993,613  | + 3  |
| California .....     | 2,779      | 435        | - 84                                       |
| Colorado .....       | 4,102      | 4,702      | + 15                                       |
| Georgia .....        | 117,321    | 113,039    | - 4  |
| Idaho .....          | 1,290      | .....      | -100                                       |
| Michigan .....       | 14,174,468 | 12,350,755 | - 13                                       |
| Minnesota .....      | 44,348,296 | 31,902,085 | - 28                                       |
| Missouri .....       | 53,546     | 79,847     | + 49                                       |
| Montana .....        | 17,751     | 3,913      | - 78                                       |
| Nevada .....         | 9,578      | .....      | -100                                       |
| New Jersey .....     | 307,733    | 63,197     | - 79                                       |
| New Mexico .....     | 205,218    | 189,371    | - 8  |
| New York .....       | 541,922    | 255,832    | - 53                                       |
| North Carolina ..... | 59,684     | 12,525     | - 79                                       |
| Ohio .....           | .....      | 244        | .....                                      |
| Pennsylvania .....   | 993,441    | 807,208    | - 19                                       |
| Tennessee .....      | 267,275    | 179,853    | - 33                                       |
| Utah .....           | 57,752     | 164,154    | +184                                       |
| Virginia .....       | 155,977    | 89,792     | - 42                                       |
| Washington .....     | .....      | 1,700      | .....                                      |
| Wisconsin .....      | 871,416    | 690,058    | - 21                                       |
| Wyoming .....        | 378,747    | 363,096    | - 4  |
|                      | 69,351,442 | 54,267,419 | - 22                                       |

(Continued on Page 36 Adv. Sec.)

## NEW FISHER POLISHING MACHINE

An independent unit for preparing metal surfaces with which separate heads can be used so that the same machine may be used for either fine grinding or for polishing.

The polisher consists of a vertical motor with a polishing disc directly connected to the motor shaft. Motor is mounted on a circular cast-iron base which has three (3) legs and holes for attaching to a table. Mounted on the base, and surrounding the motor, is a cylindrical nickel plated brass housing. On top of this housing is



bolted a nickel plated copper bowl which completely surrounds the polishing head. This bowl is provided with a drain which draws off the polishing liquid caught in the bowl. It is also provided with a nickel plated copper cover which protects the disc from dust, when not in use.

It has a 6 inch polishing head of finished cast iron with hard rubber disc on top, for holding the polishing felt. A special counterbalanced clamping device enables the operator to quickly attach or remove the felt.

The motor can be operated on either 110 volts A.C. or D.C.; normal speed about 1700 r.p.m.

Outfit supplied with polishing head and felt disc; with cord, pendant-switch and plug.

Each, \$95.00

## FISHER LEVIGATED ALUMINA

for Metallographic Polishing

This alumina is now recognized by the leading metallographists as the most satisfactory material for polishing metal surfaces for microscopical examination and photography, and is recommended in the newer text books on this subject.

**FISHER ALUMINA. Grade No. 1.** For all hard metals. One ounce with 50 ounces of distilled water makes the correct polishing solution.

Per ounce, \$1.00

**FISHER ALUMINA. Grade No. 2.** For medium hard metals. Especially suitable for cast iron bronze, brass and all nickel and copper alloys. One ounce makes 100 ounces of correct polishing solution.

Per ounce, \$1.40

**FISHER ALUMINA. Grade No. 3.** For very soft metals and other metal specimens for investigation under highest possible magnifications. One ounce makes 150 ounces of correct polishing solution.

Per ounce, \$1.80

## SCIENTIFIC MATERIALS COMPANY

"Everything for the Laboratory"

PITTSBURGH, PA.

When answering advertisements please mention "Transactions"

Iron ore mined in the United States, by mining districts and varieties,  
in 1923 and 1924, in gross tons  
(Exclusive of ore containing 5 per cent or more of manganese)

| District   | Hematite                | Brown ore              | Magnetite | Carbonate | Total      | Percentage of increase or decrease in 1924 |
|--|-------------------------|------------------------|-----------|-----------|------------|--|
| 1923   |                         |                        |           |           |            |  |
| Lake Superior <sup>a</sup> .....                     | 59,196,734              | .....                  | 88,674    | ....      | 59,285,408 | .....                                      |
| Birmingham .....                                     | 5,740,233               | 306,675                | .....     | ....      | 6,046,908  | .....                                      |
| Chattanooga .....                                    | 404,948                 | 229,102                | .....     | ....      | 634,050    | .....                                      |
| Adirondack .....                                     | .....                   | .....                  | 460,311   | ....      | 460,311    | .....                                      |
| Northern New Jersey and south-eastern New York ..... | .....                   | .....                  | 376,495   | ....      | 376,495    | .....                                      |
| Other districts .....                                | <sup>b</sup> 582,539    | <sup>b</sup> 697,071   | 1,265,144 | 3,516     | 2,548,270  | .....                                      |
|  | <sup>b</sup> 65,924,454 | <sup>b</sup> 1,232,848 | 2,190,624 | 3,516     | 69,351,442 | .....                                      |
| 1924   |                         |                        |           |           |            |  |
| Lake Superior <sup>a</sup> .....                     | 44,796,766              | .....                  | 44,953    | ....      | 44,841,719 | -24  |
| Birmingham .....                                     | 6,214,381               | 296,931                | .....     | ....      | 6,511,312  | + 8  |
| Chattanooga .....                                    | 376,693                 | 171,004                | .....     | ....      | 547,697    | -14  |
| Adirondack .....                                     | .....                   | .....                  | 197,437   | ....      | 197,437    | -57  |
| Northern New Jersey and south-eastern New York ..... | .....                   | .....                  | 110,626   | ....      | 110,626    | -71  |
| Other districts .....                                | <sup>b</sup> 714,460    | <sup>b</sup> 346,224   | 994,695   | 3,249     | 2,053,628  | -19  |
|  | <sup>b</sup> 52,102,300 | <sup>b</sup> 814,159   | 1,347,711 | 3,249     | 54,267,419 | -22  |

<sup>a</sup>Includes only those mines in Wisconsin which are in the true Lake Superior district.

<sup>b</sup>Some hematite included with brown ore.

Iron ore shipped from mines in the United States, 1923 and 1924, by States  
(Exclusive of ore containing 5 per cent or more of manganese and of ore sold for paint)

| State              | 1923       |                        | 1924       |                        | Percentage of increase or decrease |       |
|--------------------|------------|------------------------|------------|------------------------|------------------------------------|-------|
|                    | Gross tons | Value                  | Gross tons | Value                  | Quantity                           | Value |
| Alabama .....      | 6,922,663  | \$ 15,540,198          | 6,557,596  | \$ 13,927,551          | - 5                                | - 10  |
| California .....   | 2,769      | 18,665                 | 435        | (a)                    | - 94                               | ..... |
| Colorado .....     | 4,102      | (a)                    | 4,702      | (a)                    | + 15                               | ..... |
| Georgia .....      | 117,286    | 300,712                | 112,059    | 285,128                | - 4                                | - 5   |
| Idaho .....        | 1,290      | (a)                    | .....      | .....                  | -100                               | -100  |
| Michigan .....     | 14,065,561 | 54,110,070             | 11,248,641 | 35,605,902             | - 20                               | - 34  |
| Minnesota .....    | 44,556,053 | 158,402,788            | 31,076,114 | 93,311,092             | - 30                               | - 41  |
| Missouri .....     | 54,348     | 247,975                | 79,847     | 405,622                | + 47                               | + 64  |
| Montana .....      | 17,751     | 51,039                 | 3,913      | 10,846                 | - 78                               | - 79  |
| Nevada .....       | 9,578      | (a)                    | .....      | .....                  | -100                               | -100  |
| New Jersey .....   | 349,435    | 1,403,723              | 101,123    | 420,488                | - 71                               | - 70  |
| New Mexico .....   | 205,218    | (a)                    | 189,371    | (a)                    | - 8                                | ..... |
| New York .....     | 722,696    | 3,242,229              | 303,386    | 1,448,616              | - 58                               | - 55  |
| North Carolina ..  | 59,684     | 161,603                | 12,525     | 32,512                 | - 79                               | - 80  |
| Ohio .....         | .....      | .....                  | 244        | (a)                    | .....                              | ..... |
| Pennsylvania ..... | 988,586    | 2,264,485              | 807,411    | 1,881,122              | - 18                               | - 17  |
| Tennessee .....    | 266,175    | 677,753                | 179,293    | 431,682                | - 33                               | - 36  |
| Utah .....         | 57,752     | 205,936                | 164,154    | 234,348                | +184                               | + 14  |
| Virginia .....     | 200,966    | 664,240                | 91,759     | 250,279                | - 54                               | - 62  |
| Washington .....   | .....      | .....                  | 1,700      | (a)                    | .....                              | ..... |
| Wisconsin .....    | 831,412    | 2,421,194              | 786,006    | 2,044,762              | - 5                                | - 16  |
| Wyoming .....      | 378,747    | (a)                    | 363,096    | (a)                    | - 4                                | ..... |
| Undistributed .... | .....      | <sup>b</sup> 1,026,311 | .....      | <sup>b</sup> 1,017,155 | .....                              | ..... |
|                    | 69,811,472 | \$240,738,921          | 52,083,375 | \$151,307,105          | - 25                               | - 37  |

<sup>a</sup>Included under "Undistributed."

<sup>b</sup>This figure includes value for States entered as "(a)" above.

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